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COAL GAS ENGINEERING.

By ROBT. BRIGGS, C.E.

COMMON COAL GAS—ITS COMPOSITION, AND RESULTS OF COMBUSTION.—Some forty or more distinct gaseous chemical components are well known to have existence in the ordinary coal gas of the gas works, in four several groups: the first of which are gases which burn in air without, or with slight, emission of light; the second, gases which, when burned with the first for supply of heat, evolve carbon, which, becoming incandescent before burning itself, emits light; the third, incombustible gases; and the fourth, gases which are considered impurities. The first group is over four-fifths of the volume of coal gas, and is composed of only three substances or compounds, to wit: hydrogen, marsh gas and carbonic oxide; the second, which is only 7 to 9 per cent., comprises an almost endless list of hydro-carbon compounds, which are diffused, as gases or vapors, into the gases of the other groups; for the purpose of this paper this group will be con-

sidered as if composed entirely of olefiant gas (possibly most of these hydro-carbons are of the olefine series of compounds); the third comprises the carbonic acid, aqueous vapor and air, and is always 3 to 6 per cent. of coal gas; while the fourth, the impurities—ammonia and sulphur compounds; obnoxious as they are in quality, in any tolerably well purified gas the percentage of them in volume is so small, that in a discussion of results of combustion they do not become an element.

With this explanation to qualify the following statements and calculations, it is proper to say that common coal gas, of 14 to 15 candles illuminating power, has the following constituents in volumes per hundred parts: Hydrogen, H, 44 to 48; marsh gas, CH_4, 34 to 38; olefiant gas, C_2H_4, and other hydro-carbons, etc., 6 to 9; carbonic oxide, CO, 5 to 7; carbonic acid, CO_2, 1 to 3; air, 4 N+O, 1 to 3; aqueous vapor, H_2O (saturation at 40° to 60°), 1 to 2. The specific gravity of coal gas is about 0·426, which makes the volume of a pound of gas at 70° (barometer 29·9 in.) equal to 31·3 cubic feet (neglecting fractions, too small to be of consequence in this estimate) = 0·0319 lb. per cubic foot. Taking an average of the constituents of coal gas by weight, they can be reduced to 21·8 parts of hydrogen, 51·3 parts of carbon, and 13·6 parts of carbonic oxide, which are combustible; leaving 13·3 parts of non-combustible substances. The figures of the reduction of volumes to weights are as follows:

	Constituents.	Volumes per ct.	Do. average.	Specific Gravity.	H.	C.			Wt. per ct.
H	Hydrogen,	44 @ 48	45	0·0692 = 3·114	3·114		H	9·266	21·8
CH_4	Marsh gas,	34 @ 38	36	0·559 = 20·124	5·031	15·093			
C_2H_4	Olefiant gas,	6 @ 9	8	0·981 = 7·848	1·121	6·727	C	21·820	51·3
CO	Carbonic oxide,	5 @ 7	6	0·967 = 5·802				5·802	13·6
CO_2	Carbonic acid,	1 @ 3	2	1·524 = 3·048				3·048	7·2
4N+O	Air,	1 @ 3	2	1·000 = 2·000				2·000	4·6
H_2O	Vapor of water,	1 @ 2	1	0·622 = 0·622				0·622	1·5
			100		42·558	9·266	21·820	42·558	100·

From these data, the heat given out by *complete* combustion can be calculated—hydrogen gas will evolve in its chemical change to vapor of water (including the latent heat of the vapor) 62,000 units of heat, while carbon, in becoming carbonic acid, evolves 14,500 units, and carbonic oxide, in changing to the same form, evolves 4330 units—with the following result:

Combustion of 100 Pounds of Coal Gas.

Combustion.		Oxygen required.	Air required to supply oxygen.	Air required to effect complete combustion.	Units of heat per lb. of combustible	Units of heat total evolved.	Product. H_2O	Product. CO_2
H	21·8	174·4	785	1570	62000	1351600	196·2	
C	51·3	136·8	616	1232	14500	743850		188·1
CO	13·6	7·8	35	70	4330	58890		21·4
CO_2	7·2	0·						7·2
4N+O	4·6	0·						
H_2O*	1·5	0·					1·5	
	100·	319·	1436	2872		2154350	198·	217·
Deduct latent heat of 196·2 lbs. vapor of 70° @ 1065°,						208950		
Total units of heat from 100 lbs. coal gas (86·7 combustible + 13·3 of non-combustible).....						1945400		

[* This ratio of vapor of water corresponds to the condition of vapor in saturated air at the temperature of 43° or 41 per cent. humidity at 70°—perhaps a little dry for summer tests.]

Accepting these quantities for the products of combustion of 100 pounds of coal gas, the absolute temperature attained may be estimated. Three different hypotheses present themselves: the first supposes the absolute heat to be that derived from the capacity of the product to take up the entire heat generated. The second limits the expenditure of heat in producing intensity, to the air needed to supply oxygen; while the third supposes the ultimate maximum intensity to be that derived from the chemical combination of oxygen and carbon, and of oxygen and hydrogen. The last is probably the correct value for the *intensity* of the source of radiating heat from a gas light. The following table gives the three computations in the order named:

Pounds × Specific heat = Sum of weight multiplied by Specific heat.		Pounds = sum, etc.		Pounds = sum, etc.
H_2O 198 × 0·478 = 94·050	H_2O	198; 94·050	H_2O	198; 94·050
N 1117 × 0·245 = 273·665	N	1117; 273·665		
4N+O 1436 × 0·238 = 341·768				
CO_2 217 × 0·217 = 47·089	CO_2	217; 47·089	CO_2	217; 47·089
Total 2968 × 0·255 = 756·572		1532; 414·808		415; 141·139

If now the total number of units of heat, which resulted from the burning of 100 pounds of coal gas, be divided by the sum of weights of products of combustion, multiplied by their specific heat, the increment of heat to the products will be given by the result; which, added to the original or normal heat of the gas and air (here taken

at 70°), will give the absolute temperature of the products as they are assumed to exist in the three suppositions.

Supposed absolute temperature of flame of coal gas, where the products of combustion are taken to include the volume of air, which is the requisite for complete combustion:

$$= \frac{1945000}{756{\cdot}572} + 70° = 2641°.$$

Supposed absolute temperature of flame of coal gas, where the products of combustion are taken to include the air needed to supply oxygen of chemical combination:

$$= \frac{1945000}{418{\cdot}804} + 70° = 4760°.$$

Supposed absolute temperature of flame of coal gas, where only the oxygen of chemical combination is taken into the estimate:

$$= \frac{1945000}{141{\cdot}139} + 70° = 13885°.$$

At the same time we are discussing the absolute temperatures of coal gas flames, it may prove interesting to examine, separately, those of the three gases which compose it, as follows:

	Weight, pounds.	Oxygen, pounds.	Product of com.	Weight, pounds.	Specific heat.	Units heat.	Intens. of flame.
Hydrogen, H	1	8	H_2O	9	$\times 0{\cdot}475 = 4{\cdot}275$	52447	$(12268° + 70° = 12338°$
Carbon, C	1	2 2-3	CO_2	3 2-3	$\times 0{\cdot}217 = 0{\cdot}796$	14500	$(18223° + 70° = 18293°$
Carb. ox., CO	1	4-7	CO_2	1 4-7	$\times 0{\cdot}217 = 0{\cdot}341$	4329	$(12694° + 70° = 12764°$

The value for the heat effect of one pound of hydrogen is derived in the same way as was used in the estimate for coal gas, as follows:

Total heat effect of 1 lb. of hydrogen,	= 62,032 units.
Deduct latent heat of 9 lbs. vapor of 70°, 1065°, ...	= 9,585 "
Heat effect of 1 lb. of hydrogen, without condensation of vapor, .	= 52,447 "

These estimates of the heat of the flame of gases have taken for granted the constancy of the relative values of specific heats at high temperatures, and the results may therefore be considered as only approximations of the truth; still they give, probably, the most nearly correct estimate of the values of intensity possible.

The heat evolved by the burning of coal gas is dispersed in two ways—as radiant, and as convected or imparted heat. With the

open burner, it is fair to assume that a large portion of the heat is dispersed as radiant heat. According to Peclet, 50 per cent. of the heat of a flame of burning wood or coal is dispersed as radiant heat, and it does not seem to be an improper assumption, that one-half the heat of burning of coal gas will be dispersed as radiant heat, and the other will be communicated to the gases of combustion, and disseminated by convection and intermixture with the surrounding air. The limited base from which the flame of a gas burner emerges, as compared to the magnitude of the flame or burning surface, prevents the loss or expenditure of radiant heat upon the fuel (which would again impart its heat to air in contact before burning), and thus reduces the convected heat to its least quantity. The supposition appears the more reasonable when we consider the enormous intensity of the heat of chemical combination; nearly 14000°, as above indicated, when unmixed with other gases to absorb its heat. If we proceed on this supposition, it follows that the convected heat of 100 pounds of coal gas becomes one-half of $1945400 = 972700$ units; and this heat imparted to the products of combustion, when they are taken to include the volume of air necessary to effect complete combustion, gives the temperature of these products:

$$= \frac{972500}{756{\cdot}572} + 70° = 1356°.$$

The relations of volumes of the products of combustion of coal gas to the weights as ascertained, can be seen by the following table—estimated at 70°:

Product.	Spec. grav.	Wt. per cu. ft.	Cubic ft. per pound.		Wt. of product.		Cu. ft. of product.	Cu. ft. per ft. of gas.	Vol. per ct. of product.
H_2O	0·622	0·0466	21·45	×	198	=	4247	1·355	10·45
N	0·972	0·0729	13·73	×	1117	=	15332	4·891	37·73
4N+O	1·000	0·0750	13·34	×	1436	=	19158	6·111	47·15
CO_2	1·524	0·1142	8·754	×	217	=	1900	0·606	4·67
					2968	=	40637	12·963	100·00
Gas	0·426	0·0319	31·35	×	100	=	3135	1	7·71
Oxygen*	1·106	0·0829	12·07	×	319	=	3849	1·228	9·47
Air	1·000	0·0750	13·34	×	1432	=	19103	6·094	47·01
Dbl. Air	1·000	0·0750	13·34	×	2868	=	38259	12·204	94·15
Heat total, units			1945400					622	
Heat convected, units			972700					311	

[* The oxygen taken is that of actual combination, and represents the quantity needed, with coal gas, when used for the lime light or Bunsen burner.]

The preceding computation can be verified by another arrangement of data, in which volumes alone appear, taking the second column from the table of reduction of volumes to weight:

	100 vols. × spec. grav.	H.	C.	O.	N.		
Hydrogen, H	3·114	3·114					
Marsh gas, CH_2	20·124	5·031	15·093				
Olefines, C_2H_4	7·848	1·121	6·727				
Carbonic oxide, CO	5·802		2·487	3·315			
Carbonic acid, CO_2	3·048		0·831	2·217			
Air, 4N+O	2·000			0·444	1·556		
Aqueous vapor, H_2O	0·622	0·069		0·536			
100 vols. × spec. grav., totals	42·558	9·335	25·138	6·529	1·556	H_2O	CO_2
Per cu. ft. gas, weights, lbs.	0·0319	0·0070	0·0188	0·0049	0·0012	0·063	0·069
" " volumes, cu. ft.	1·000	1·349		0·059	0·017	1·351	0·605

Result of combustion of hydrogen and carbon with definite proportion of oxyg.

In general, the combustion of all substances, oils, fat acids, or gases used for illuminating purposes, is unquestionably perfect combustion of the carbon and hydrogen elements into carbonic acid and aqueous vapor. Neither smoke nor carbonic oxide, nor hydrogen in free or combined state, other than water, can be found in the air of any room where the lighting is at all satisfactory to the occupants, and the production of heat, as has been estimated, becomes one of the positive facts in physics beyond question as to existence and quantity. With the case of the open gas burner, it is possible that one-half the heat of the flame is dispersed as radiant heat, but this dispersal does not, however, get rid of the heat in a room; it merely transfers it to solid bodies of less temperature, more or less remote from the flame, which again are cooled in great measure by contact of the air of room, which takes up their excess of warmth, so that the heat emanating from a burner really is nearly all expended in the air. But when the burners are shaded by glass or other shades, and particularly for argand burners with chimneys, the larger part of the radiant heat is cut off by the shade or chimney, or both together, and imparted to an unknown volume of air which accompanies the air for or of combustion. As a practical application, it may be well to consider what volumes of air are requisite to disperse the heat of gas lights if the air in any part of a room is limited to some definite temperature.

The following table exhibits the effect of gas burning from a single burner of the usual sizes:

(All figures refer to quantities per hour—air of room and gas at 70°.)

Gas burned, cu. ft.,	1	3	3½	4	4½	5	6	8
Carbonic acid evolved, cu. ft.,	0·606	1·82	2·12	2·42	2·73	3·03	4·24	4·84
Aqueous vapor " " "	1·355	4·07	4·74	5·42	7·10	7·78	8·13	10·84
" " " lbs.,	0·063	0·19	0·221	0·253	0·285	0·317	0·38	0·506
Oxygen removed, cu. ft.,	1·228	3·68	4·30	4·91	5·52	6·14	7·87	8·60
Heat produced, units,	622	1866	2177	2488	2799	3110	3732	4976
Coal to produce equal heat, lbs.	0·062	0·19	0·22	0·25	0·28	0·31	0·37	0·50
Air supply = 10 cu. ft. per min. per cu. ft. gas } cu. ft.,	600	1800	2100	2400	2700	3000	3600	4800

With the supply of air to each gas burner given by the preceding table, the temperature of the current ascending from open burners, where one-half the heat is supposed to be radiated away, becomes 99°; while the temperature of the same current arising from an argand burner, where the glass chimney will have intercepted the radiant heat, becomes 128°.

The figures for this temperature are thus obtained: The weight of air at 70° is 0·075 pound per cubic foot, which, multiplied by 0·238, the specific heat of air, gives 0·01785 unit as the capacity of one cubic foot of air for each degree Fahr.; with 600 feet of air supply per hour to 1 foot of gas, the capacity of the 600 feet becomes 10·71 units for each degree of elevation of temperature; and to absorb 622 units by the 600 cubic feet of air, the latter will become heated

$$\frac{622}{10{\cdot}71} = 58°,$$

which, added to the 70° of primary temperature, give 128° as the final one when all the heat is taken up by the air. When but half the heat is assumed to be given to the air, we have $29° + 70° = 99°$.

The computation of the temperature to accompany any other volume of air supply is easy. Thus, if for each cubic foot of gas burned per hour—normal temperature 70°:

Air supply per minute, cu. ft.,	5	10	15	20	25	30
Corresponding air supply per hour, cu. f.,	300	600	900	1200	1500	1800
Temperature of air ascending from open burners, }	128°	99°	89°	84½°	81½°	79½°
Temperature of air ascending from argand burners, }	187°	128°	118°	99°	93°	89°

The estimate of weight of coal, the consumption of which will produce an equal effect in warming a room with gas burning, is not based

on the theoretical value of coal as a producer of heat, but upon average usual results from heating apparatus, as steam or hot water apparatus, hot air furnaces of best construction, or close stoves, in utilizing the heat of the fuel. That is, 10,000 units of heat have been assumed to be given out efficiently by the consumption of one pound of good anthracite coal.

The capacity of the air requisite for dispersal of the heat of a gas flame, to take up the moisture generated by the process of burning, can be investigated. According to the best authority (Regnault, from Guyot's tables), saturated air has the following quantities of moisture per cubic foot of air:

Temperature of air,	70°	75°	80°	85°	90°	95°	100°	105°
Weight of moisture, lbs.,	0·0011	0·0013	0·0016	0·0018	0·0021	0·0024	0·0028	0·0032

If it is assumed that the air of supply is 70°, and has 60 per cent. of saturation, then such air has 0·0007 pound of water to each cubic foot, whence the capacity of this air, to take up moisture in becoming saturated, is:

0·0004 0·0006 0·0009 0·0011 0·0014 0·0017 0·0021 0·0025

and there will be needed to carry off the 0·063 lb. of moisture which the burning of each cubic foot of gas per hour evolves:

Air at given temperatures, cu. ft.,	158	105	70	57	45	37	30	25

Comparison of these quantities, with the volume of air supply, and corresponding resulting temperatures as given in the previous table, demonstrates that the moisture generated by gas burning will be absorbed, in all cases, into the air for dispersal of heat.

While it appears to be impossible to discern any error in the method and data of this inquiry, and the mathematical accuracy (errors of computation excepted) of the results seems to be unquestionable, yet their application to practice is found to need great qualification. The material products of combustion, *i. e.*, aqueous vapor and carbonic acid, and the corresponding abstraction of oxygen from the air of a room, are established facts, but it is very difficult to account for the dispersion of the heat. Great allowance is needful for conductivity of the enclosing surfaces—floors, walls, ceilings, windows and doors—and also for fresh air currents, surreptitious or otherwise, before the heat imparted to the air, as derived from these computations, will conform to what is really found to be the heat effect

of gas lighting. For instance, a 4 ft. gas burner would be held to be ample for lighting a small bed-room, and such a burner is frequently permitted to remain burning all night in a room of, not to exceed, 800 cubic feet capacity. This burner, by the computation, would produce 2488 units of heat each hour. In moderate weather no considerable loss of heat from the surfaces enclosing the room is supposable, and the figures give 7200 cubic feet of air per hour (or 120 feet per minute) as the indispensable necessity to keep down the temperature to 19° above the normal one. To be sure, the current of gases ascending from the burner will reach the ceiling of the room at a greatly elevated temperature, perhaps 140° even, and a stratum of hot air next the ceiling be formed (unless some arrangement of ventilation removes the hot air at once), and then the conductivity of the ceiling will be brought into action, but yet it is hard to feel satisfied that this means is sufficient to account for all the loss of heat apparently demanded.

It must be admitted that further inquiry and experiment are wanted to elucidate the subject of the dispersal of heat of gas lights, and perhaps to review the entire subject of the quantity of heat produced by them.

THE OIL SANDS OF PENNSYLVANIA.[1]

By Chas. A. Ashburner, M. S., Asst. Second Geological Survey of Pennsylvania.

The recent discussion among the producers, shippers and refiners of the petroleum of Pennsylvania, as to the advisability of the State Legislature passing a free pipe line law, which will permit the laying of pipes for the running of the crude material from the producing regions to the seaboard, has brought many points of interest, connected with one of the greatest industries of our State, before unnoticed, to the attention of the public.

One of the most important questions to the petroleum miner, and one which even the more enlightened of our oil men can answer only

[1] Paper read before the Engineers' Club of Philadelphia, Feb. 16th, 1878.

in a very vague and uncertain way, is, where is petroleum found? The question is an exceedingly broad one, and involves many considerations which cannot reasonably be noticed within the limits of a brief paper. The origin of petroleum, its connection with the sand in which it is found, the influence of the character of the oil sands on their productiveness, the relation of the surface rocks to the oil sands, and the bearing of surface indications upon the position of underlying oil belts, the connection between petroleum and natural gas, etc., are all vital questions which must be met before we can say where petroleum is found and where we may locate profitable wells.

I do not wish to anticipate any of the conclusions which our present Geological Survey may advance, to meet any or all of these questions which suggest themselves so pertinently to those interested in the petroleum industry, or express any views on the more important and practical question as to the position of producing territory, and the location of profitable wells. I have thought it would be of interest to the members of the Engineers' Club to give, in a general way, a vertical section of the rock formations, showing the relative position of all the oil horizons of Western Pennsylvania, together with an estimate of the daily production of each horizon.

That portion of the State in which petroleum has been found, lies entirely west of a line drawn across the State, from the State line at the southeastern corner of Greene County to the State line at the northeastern corner of McKean County.

For convenience of description, the oil regions may be divided into three groups or districts—the southwestern, the western and the northern.

The southwestern district may be said to include that part of the state south of the Ohio River, and west of the Monongahela River; the western, better known among the producers as the "lower country," lies in the water-basin of the Alleghany River, between Pittsburg, on the south, and the Philadelphia and Erie Railroad, on the north; and the third or northern district lies entirely north of the Philadelphia and Erie Railroad, in the counties of Warren and McKean, and extends ten miles into the State of New York.

The strata of Western Pennsylvania lie comparatively horizontal. The average dip of the rock from Bradford, near the State line, to Pittsburg, is about 18 ft. to the mile; that is, a rock which occurs at

water level at Bradford, at an elevation of 1450 ft. above ocean level, would be found at Pittsburg about 750 ft. below the same datum, or 1500 ft. below water level. Three thousand feet of the stratified rocks of the Carboniferous and Devonian Ages in Pennsylvania, have been found to contain petroleum. The highest stratum in which oil is found, occurs in the coal measures, 165 ft. below the Pittsburg coal seam, in Greene County; while the lowest occurs about 3200 ft. below the geological position of the Pittsburg coal seam in McKean County.

If we should drill a well in Greene County 3200 ft. deep, starting on the Pittsburg coal, we would pass through the horizon of all the sands and sandstones in which the petroleum of our State has been found.

This estimate is made on the assumption, that if the coal measures up to the Pittsburg seam should be restored in McKean County, the lowest oil-bearing rock in the northern district would be found the same depth below the Pittsburg coal, as the geological horizon of the same sand would be found below the same coal-bed in Greene County.

From observations in the western part of the State, we know that the rocks are subject to very marked and rapid changes in their thicknesses, in comparatively short distances. What the change in rock thickness may prove to be, between McKean and Greene Counties, we have not sufficient facts at hand to assert. Whether the total thickness of the stratified rocks between the Pittsburg coal and the "Sartwell" or lowest oil horizon, at localities between the two counties, shall be found to be a variable quantity, or much greater or much less than the above estimate, the fact, in itself, will not defeat the object of this paper, which is intended to point out the relative, and not the absolute, position of the oil sands one to another.

The petroleum, in the southwestern district, comes from the highest rocks; that in the northern, comes from the lowest; while the producing sands of the western district are found intermediate between the other two groups of rocks.

The southwestern district "oil-sand group" is about 800 feet thick, and is composed of three sandstone members, separated by intervals containing coal seams, slate and shale. The following is a general section of the group, by Prof. Stevenson:

1. Morgantown Sandstone, Dunkard Creek; thickness, 66 ft.
Lower Barren Coal Measures, shales and slates; thickness, 194 ft.

2. Mahoning Sandstone, Dunkard, Whiteley and Dunlap's Creeks; thickness, 50 ft.
Lower Productive Coal Measures; thickness, 85 ft.

3. Piedmont Sandstone and Coal Conglomerate, Dunkard Creek; thickness, 400 ft.

The first or upper oil sandstone shows considerable variation, and is oftentimes replaced by shale. It is a noticeable fact that in this case the shale contains no oil.

The Mahoning or second sandstone is quite constant in thickness, and is the principal repository of petroleum in the southwestern district. It frequently contains conglomerate layers.

The third or lower sandstone is made up of three members, an upper and lower sandstone member, separated by about 30 to 40 ft. of shale and coal. The upper member is regarded as the oil-bearing rock. The lower member, or Piedmont Sandstone, is the representative of the coal conglomerate or millstone grit.

Some of the characteristics of this district are quite different from those of the western or northern districts. In drilling, small crevices in the oil sands are of frequent occurrence; and it is a striking fact that the oil is said never to have been found except where a crevice was struck. The producers in this field have considered this fact necessary to the original production of oil itself.

According to Prof. Stevenson, the oil in nowise owes its origin to disturbance of strata, and the only effect of the disturbance has been to provide reservoirs for the oil in the rock already oil-bearing.

Between the bottom of the coal conglomerate, which is the lowest member of the lowest oil-producing sandstone of the southwestern district, and the "first oil sand," which is the highest producing sandstone of the western district, there is an interval of from 650 to 700 ft. of shales and sandstones, forming the Barren Oil Measures, or Mountain Sand group. These rocks are perfectly barren of any economical strata; they contain no coal, iron or oil. In Butler County this group often contains gas.

The Greene County "oil sand group," and the upper part of the Barren Oil Measures, belong to the Carboniferous Age, while

the oil sands of the western and northern districts are Devonian rocks.

The following is a general section of the oil sands of the western district:

First sand, ...	40 ft. thick.
Interval, ...	105 ft.
Second sand, ...	25 ft. thick.
Interval, ...	110 ft.
Third sand, ...	35 ft. thick.
Total thickness of the group, . .	315 ft.

All the oil from Clarion, Butler and Venango Counties, which comprise our most productive field, comes from this group, and from one of the representatives of the three sands. These sands are sometimes split up into several members, giving rise to what are known as the "fourth," "fifth," and "sixth" sands of Oil Creek.

The first sand produces a heavy lubricating oil from 30° to 35° gravity; the second, an oil of about 40° gravity; and the third sand, the usual light oil, from 45° to 50° gravity.

The third sand of this district is the most productive, and supplies most of the oil of commerce. According to Mr. Carll, assistant in the Oil Regions, "the well records along the 'green oil belt' in Venango County, show a great uniformity in the arrangement of the sand rocks. They are sharply defined, massive, and lie at regular intervals. Going southeast from this belt, they gradually split into several members, fine down in their composition, and shade away into shales. Going to the northwest, the third sand terminates rather abruptly—the second sand overlaps it, and continues a mile or two farther; the first sand overlaps the second, and extends, in some places, a long distance beyond. The majority of the wells producing from the first and second sands, are located along these overlapping edges of the sand rocks.

"Wherever the third or lowest sand is adapted to the production of oil, the main deposit is found in it, and not in the sands above. The first and second sands, although of good quality, do not produce oil along the centre of the belt. In some wells, it is true, oil has

been obtained from all three of the sands. These wells are not on the axis, but near the edge of the third sand; and but a short distance further from the centre, no third sand can be found."

These are very suggestive facts, and seem to point to the conclusion that the oil sands are merely reservoirs, which have acted as sponges in absorbing the oil which has ascended from a much greater depth. The oil in this case would not be indigenous to the rock in which it is found.

If indigenous, why is the bulk of the "first sand oil" found in the edges of the first sand which overlap or extend beyond the edges of the second and third sands? The same question suggests itself in regard to the most productive portions of the second sand.

Between the "third oil sand" of the western district and the Warren sand of the northern district, there is an interval of about 600 ft. of shale, which is entirely barren. The Warren oil sand is very irregular in character, and the oil is found at horizons varying from 600 to 800 ft. below the Venango third sand.

The oil obtained from the Warren horizon resembles very much the "third sand oil."

Among many of the producers the oil is known as "slush oil," on account of the irregular and poor quality of the sand, and the rapid diminution in the production of the wells, which are large producers when first struck.

The productive horizon of the Bradford oil belt in McKean County and Cattaraugus County, New York, occurs probably 300 ft., more or less, below the Warren horizon. The sand in the Bradford belt is finer and closer in texture than that of any other producing belt in Pennsylvania; it is also more constant in character over a wide area. These facts have much to do with the small percentage of risk which the producer experiences in obtaining "dry holes," or non-producing wells. The Bradford belt is the surest and safest territory in which to operate.

Of the wells completed in November in the Butler, Parker and Clarion districts, 14·8 per cent. were "dry holes;" while in the Bradford district only 6·6 per cent. were "dry holes." This is more than the usual monthly average of "dry holes" in Bradford, on account of the great number of "wild cat" or test wells which were drilled.

The oil is of about the same gravity as the "third sand oil," but somewhat different in character. On account of the difference in the sand and in the oil, the Bradford wells are never pumped continuously, but "by heads," or at regular intervals. This is found necessary, in order to keep the sand open and porous. When the interstices of the sand become "choked" by the heavier parts of the oil, the sand is broken up and loosened by nitro-glycerine torpedoes, which are lowered to the depth of the producing sand and exploded.

A great deal of the oil obtained from the Bradford belt, along the State line, is found several hundred feet above the regular producing sand. The horizon of this oil may prove to be the same as the horizon of the Warren oil.

The lowest oil found in the northern district, and, in fact, in Pennsylvania, comes from what I have called the "Sartwell oil sand," which has but recently been discovered in Liberty Township, McKean County. This horizon is, probably, 400 ft. below the Bradford sand; it has not as yet been thoroughly tested; at present it is non-productive.

Petroleum has never been found in the three groups of oil measures in the same locality. As the oil sands of the southwestern and western district outcrop, or come to the surface, in the northern district, we may never expect to find oil in them north of the Philadelphia and Erie Railroad. The question as to whether we will ever find the northern district oil in the western district, and the oil of both of these districts in the southwestern district, is a very suggestive one. If our future explorations shall prove such to be the case, we are safe in the assertion that, at the present price of crude oil, the wells would be too deep and too expensive to warrant the development.

Production.

I am unable to state how much petroleum is produced in the southwestern district. Quite extensive developments were made in Greene County last fall, and I am informed, on good authority, that one of the new wells was producing 50 barrels a day. No oil territory has yet been found in Washington County.

The following table shows the production in the western district, in November last:

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Name of Districts.	No. of bbls. of oil produced in the month.	Average per day for the month of 30 days.	No. of wells producing.	No. of wells drilling.	No. of wells completed in November.	Aggregate daily production of new wells.	Daily Average of new wells.	No. of Rigs building.	Dry holes in Nov.
Butler, . . . Parker, . . . Clarion, . . .	709170	23639	4470	275	209	2617	12½	159	31
Scrubgrass, . .	120000	4000	275	10	12	162	13½	9	2
Franklin, . .	12000	400	370	10	6	42	7	7	2
Reno, . . .	3000	100	31	.....	.....	.....	.....	.....	.....
Oil City, . .	24000	800	365	10	5	32	6½	8	2
Rouseville, . .	12000	400	200	3	3	21	7	2	1
Rynd Farm, .	12000	400	125	2	2	14	7	2	.....
Columbia, . .	3750	125	31	.....	.....	.....	.....	.....	.....
Petroleum Cr. .	3000	100	50	1	2	10	5	1	1
Shamburg, . .	6000	200	96	1	2	12	6	1	.....
Titusville, . .	45000	1500	768	10	10	80	8	9	3
Pithole, . . .	6000	200	78	2	2	6	3	2	1
Fagundas, . .	6000	200	150	1	4	16	4	1	2
Tidioute, . .	12000	400	83	5	6	42	7	4	2
Beaver, . . .	7500	250	144	12	4	20	5	3	1
Totals, . .	981420	32714	7236	342	267	.....	.....	208	48

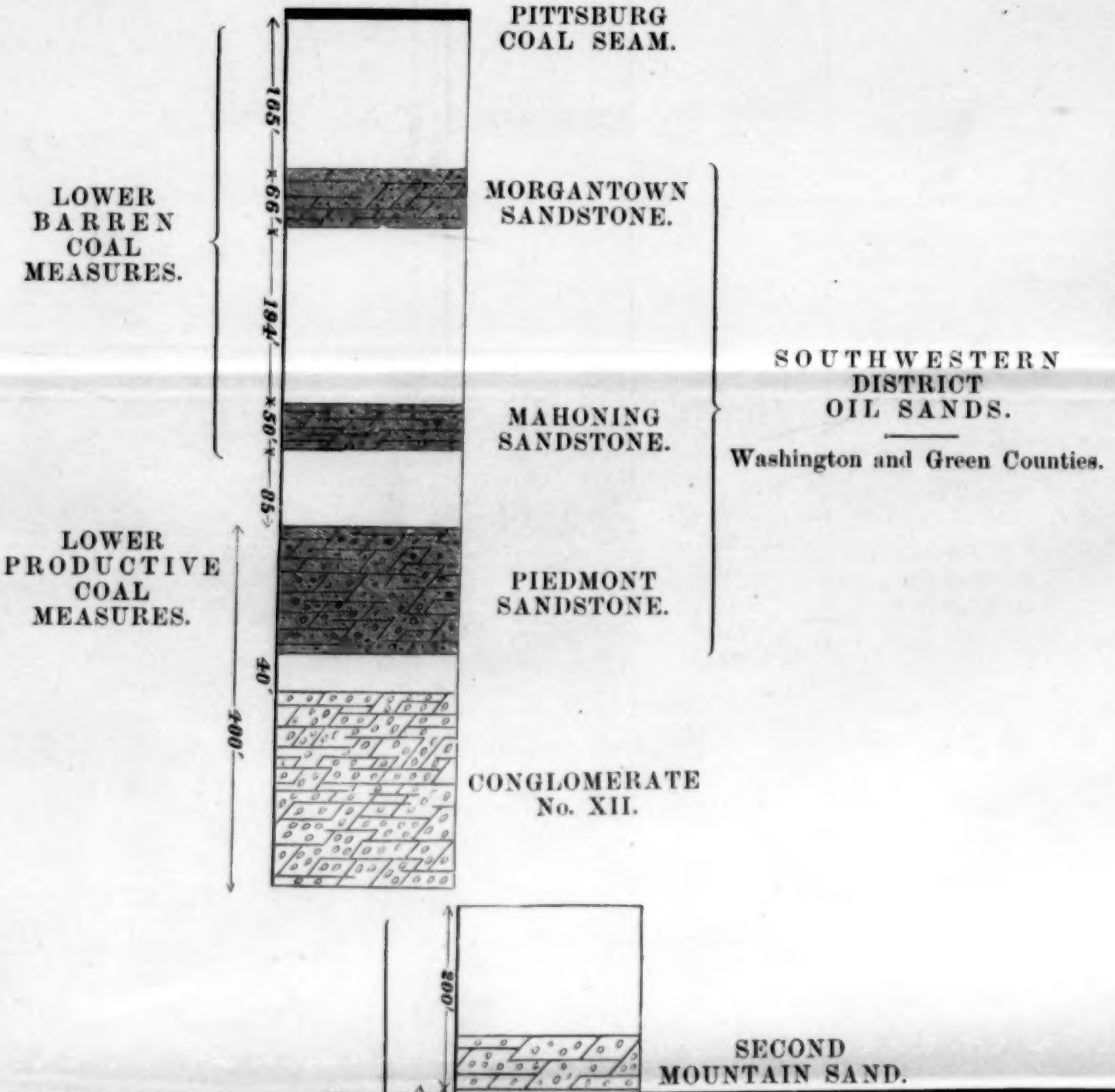
The following is the production, for the same month, in the northern district:

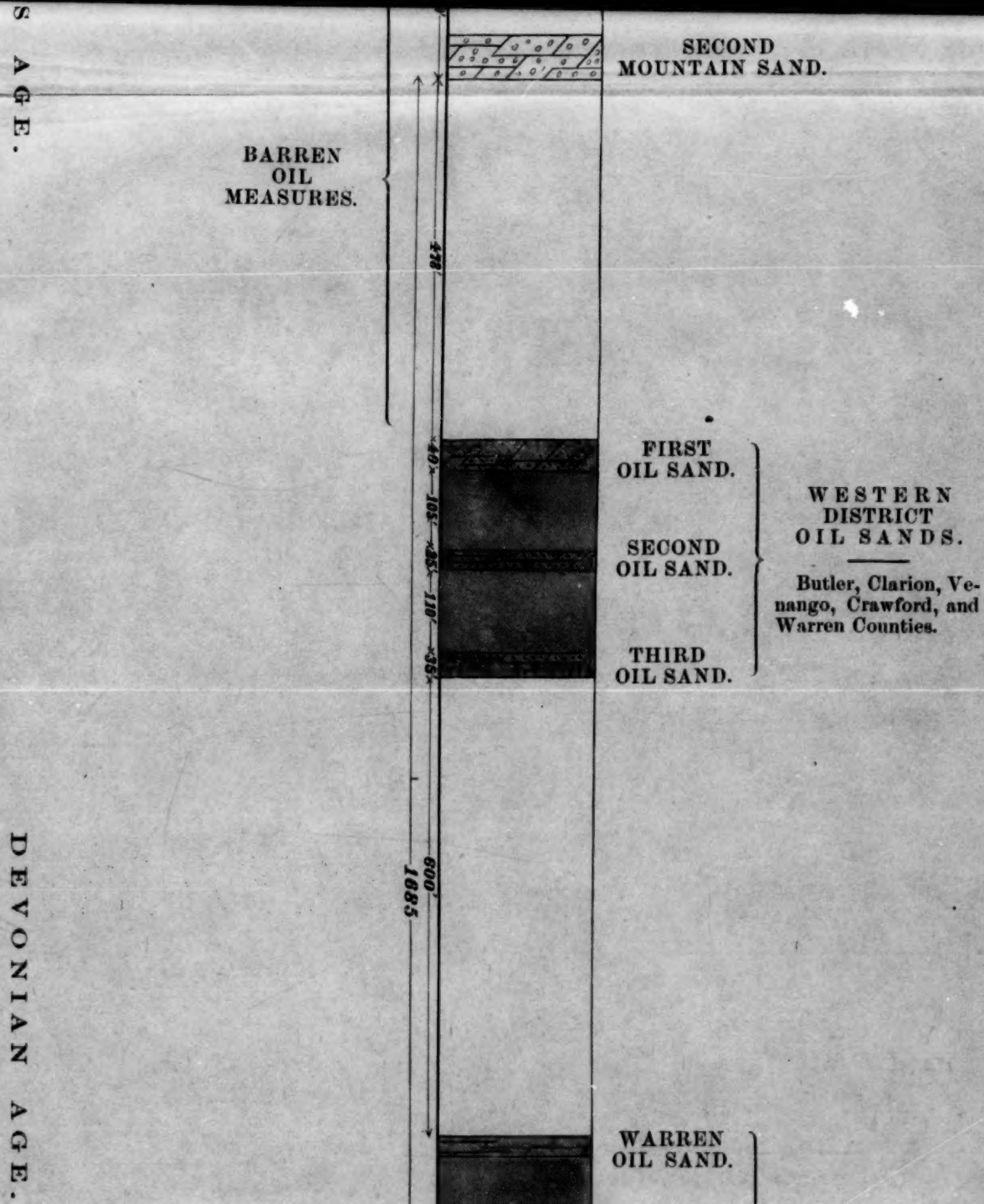
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Warren, . .	12000	400	122	5	4	28	7	3	1
Bradford, . .	180000	6000	965	218	120	1200	10	152	8
Totals, . .	192000	6400	1087	223	124	.....	.....	155	9

The total daily production for November, in the western and northern districts, was 39,114 barrels; in the month of October the same districts produced 40,946 barrels per day. This does not

SECTION OF THE PETROLEUM ROCKS OF WESTERN PENNSYLVANIA.

CHARLES A. ASHBURNER, M. S.




S AGE.
SECOND MOUNTAIN SAND.
BARREN OIL MEASURES.
478'
40'
105'
35'
110'
35'
FIRST OIL SAND.
SECOND OIL SAND.
THIRD OIL SAND.
WESTERN DISTRICT OIL SANDS.
Butler, Clarion, Venango, Crawford, and Warren Counties.
1685'
600'
DEVONIAN AGE.
WARREN OIL SAND.

A G E.

WARREN OIL SAND.

BRADFORD OIL SAND.

SARTWELL OIL SAND.

NORTHERN DISTRICT OIL SANDS.

Warren and McKean Counties.

McKean County.

SCALE, 200′ = 1″.

NOTE.—The shaded portion of the section shows the rocks in which petroleum has been found.

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necessarily show a decrease in the actual production; it is probably an error in the estimates.

The above figures were taken from the *Petroleum Reporter*. From reports made to me during the past week, the Warren district is said to be producing nearly 500 barrels, while the Bradford daily production approaches 8500 barrels. Of the Bradford production, about four-fifths come from the regular Bradford sand, and one-fifth from the higher horizons in the "slush oil" wells.

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CRANK PINS AND JOURNALS.[1]

By WILLIAM D. MARKS, Whitney Professor of Dynamical Engineering, University of Pennsylvania.

(15) THE CRANK PIN.—The crank pin has ever been one of the most troublesome parts of the steam engine to the mechanical engineer. The mere determination of its proportions, so that it will not break under the strain put upon it by the pressure of the steam upon the piston head, does not suffice, and often results in trouble from heating when the engine is at work. It therefore becomes a first consideration to so proportion crank pins as to prevent heating, their strength being a matter of secondary importance to be afterwards investigated, if it is deemed necessary to do it.

Before taking up the mathematical part of our consideration, it will be of practical value to quote, from the writings of General Morin, the following remarks:

"But it is proper to observe, that from the form itself of the rubbing body (cylindrical), the pressure is exerted upon a less extent of surface, according to the smallness of the diameter of the journal, and that unguents are more easily expelled with small than with large journals. This circumstance has a great influence upon the intensity of friction, and upon the value of its ratio to the pressure.

"The motion of rotation tends of itself to expel certain unguents, and to bring the surfaces to a simply unctuous state. The old mode of greasing, still used in many cases, consisted simply in turning on

[1] An extract from a course of lectures on "The Relative Proportions of the Steam Engine."

the oil, or spreading the lard or tallow upon the surface of the rubbing, and in renewing the operation several times in a day.

"We may thus, with care, prevent the rapid wear of journals and their boxes; but with an imperfect renewal of the unguent, the friction may attain ·07, ·08, or even ·10 of the pressure.

"If, on the other hand, we use contrivances which renew the unguent, without cessation, in sufficient quantities, the rubbing surfaces are maintained in a perfect and constant state of lubrication, and the friction falls as low as ·05 or ·03 of the pressure, and probably still lower.

"The polished surfaces, operated in these favorable conditions, became more and more perfect, and it is not surprising that the friction should fall far below the limits above indicated." (Bennett's Morin, pp. 307–8.

If the unguents are expelled by extreme pressure, so that the surfaces are simply unctuous, the friction increases rapidly, and the surfaces begin to heat and wear immediately.

These statements apply with equal force to cast iron and cast iron; cast iron and wrought iron; cast iron and brass or Babbitt's metal; or with steel or wrought iron in the place of cast iron.

The supposed superiority of brass or Babbitt's metal lined boxes over iron boxes, in positions very liable to heating, lies in their greater softness and conductivity for heat. Brass will conduct heat away from two to four times as rapidly as iron. However, the film of unguent interposed may render the conductivity of brass of less avail than is generally supposed, and the advantage lies only in the fact that being a softer metal, in case of heating, the surface of the softer metal receives the principal damage.

It is, perhaps, good practice to use brass or soft metal wherever the pressure exceeds 125 lbs. per square inch of projected area. At lower pressures an ordinary good lubricating oil may be relied upon to form a film, and run without breaking at ordinary speeds. (Winter strained lard oil was the lubricant used, diameter of journal 3 inches, making 120 revolutions per minute. But a few experiments were made. The continuity of the film of lubricant is affected by so many different conditions, that it is impossible to fix any exact limit of pressure.)

With soft metal or brass bearings, good results can be obtained at pressures of 1000 lbs. or more per square inch of projected area; if,

however, the film of unguent does break at these higher pressures, heating begins almost instantly, and if the surfaces in contact are both of hard metal, as iron and iron, injury to both at once results, while if the boxes are brass or some of the softer metals, the continuity of the surface film may be restored by increased lubrication, or by stopping and cooling as soon as heating is observed.

Several expedients are used to keep bearings, which have a tendency to heat, cool.

The introduction of rotten stone, or sulphur with oil, is perhaps the best. Quicksilver, or lead-filings, introduced with oil, coat the rubbing surfaces, and diminish the heating where the rubbing surfaces are very much scored.

A great increase of the velocity of the rubbing surfaces renders bearings more liable to heat than a great increase in pressure, although the total amount of work done by friction is the same in both cases, and is probably accounted for by the more rapid expulsion of the lubricant.

As the cause of the heating of bearings, when they are of tolerably good workmanship, is the transformation of the work of friction into heat, we see that it is necessary to reduce the friction, as much as possible, by the perfect smoothness of surfaces in contact, the interposition of lubricants, and the reduction of the speed and pressure upon the rubbing surfaces.

In all machines there is a limit, below which we cannot reduce the speed and pressure of the rubbing surfaces, and we must, therefore, so proportion journal bearings as to cause no more work due to friction, *i. e.* heat, to be produced than can be conveyed away by the unguents, the atmosphere, and the conductivity of the metals, without raising the temperature of the bearing appreciably.

From the statistics of the working of the crank pins of four screw propellers in the United States Navy (Van Buren, "Strength of Iron Parts of Steam Machinery," page 24), we take the following statement and table:

"The crank pins of these vessels worked cool, giving but little trouble, which is the exception rather than the rule for screw engines."

The projected area of crank pin journal, given in column 7, is that rectangular area formed by a central section of the crank pin journal, in the direction of its length.

Columns 1, 2, 4, 5, and 6, are given. Columns 3, 7, 8, 9, 10, and 11, are calculated from them.

In calculating column 9 from columns 3 and 8, we have assumed the coefficient of friction at ·05, which is the highest value given by Gen'l Morin for constant lubrication, and the most probable in the present cases.

Column 11 is derived from columns 3 and 7. Column 10 is derived from columns 7 and 9.

Name of Vessel.	1. Diameter of steam cyl.	2. Pressure per sq. inch.	3. Total force of steam pressure on piston head.	4. No. of strokes per minute.	5. Length of crank pin.	6. Diameter of crank pin.	7. Projected area of crank pin.	8. Velocity of rubbing surfaces, in feet, per minute.	9. Total work of friction in foot pounds per minute.	10. Work of friction per sq. inch of projected area in foot-pounds per minute.	11. Pressure per sq. inch of projected area.
	in.	lbs.	lbs.		in.	in.	sq. in.				
Swatara.....	36	40	40716	160	12	8·5	102·	178·	362372	3552·6	399·5
Saco.....	30	40	28274	180	9	7·5	67·5	176·7	249801	3700·7	419·
Wampanoag.....	100	40	314160	62	27	16·	432·	129·8	2038898	4719·7	727·2
Wabash.....	72	28	114002	100	16	15·	240·	196·3	1118910	4662·1	475·
Averages										4159·	505·

From column 10 of the table, we find the average amount of work per square inch of projected area of crank pin journal, which, in the cases cited, has been borne without heating, to be 4159 ft. lbs. per minute, and in making use of this quantity in our subsequent calculations, we are on the safe side, if the coefficient of friction (assumed at ·05) has not been taken too small.

Let d = the diameter of the piston head in inches.

Let P = the mean pressure in the steam cylinder in pounds per square inch.

Then, $7854\ d^2P$ = the mean pressure on the piston head in pounds.

Let f = the coefficient of friction.

Let l_3 = the length of the crank pin journal in inches.

Let d_3 = the diameter of the crank pin journal in inches.

The mean *force* of friction at the rubbing surfaces of any crank pin journal, per square inch of projected area, is

$$= \cdot 7854\, f \frac{P d^2}{l_3 d_3}.$$

Let N = the number of strokes per minute (= twice the number of revolutions).

Let w = the work of friction per minute.

The space passed over by the force due to friction, in one minute,

$$= \frac{\pi}{2} N d_3 = 1 \cdot 5708\, N d_3 \text{ inches},$$

and we have for the work of friction, *i. e.*, heat, per minute,

$$w = 1 \cdot 5708 \times \cdot 7854\, f \frac{P N d^2}{l_3} \text{ inch lbs.}$$

From this formula the diameter of the crank pin journal (d_3) has vanished. Why it has vanished will be understood when we observe that the force per square inch of projected area, due to friction, is inversely as the diameter of the journal; while the space passed over by this force is directly as its diameter.

Replacing w in the last formula by the mean value derived from column 10 of the table, = 4159 ft. lbs. = 49908 inch lbs., we have

$$49908 = 1 \cdot 2337\, f \frac{P N d^2}{l_3}.$$

Therefore, $l_3 = \cdot 0000247\, f\, P\, N\, d^2$, ... (20).

Considering formula (20), we see that the length of the crank pin increases and decreases with the coefficient of friction, the mean steam pressure per square inch, the number of strokes per minute, and with the square of the diameter of the steam cylinder.

A consideration of the component formulæ of (20), shows that as the crank pin journal decreases in size, the pressure per square inch becomes greater; but if this reduction in size is obtained by a diminution of the diameter (d_3) of the crank pin journal, the work per square inch of projected area is not increased, for the velocity of the rubbing surfaces, by this means, is decreased in the same ratio as the pressure is increased.

Within reasonable limits, as to pressure and speed of rubbing surfaces, the general statement may be made:

The longer any bearing, which has a given number of revolutions and a given pressure to sustain, is made, the cooler it will work, and its diameter has no effect upon its heating.

Example:

Let $d = 30''$, $N = 180$, and $P = 40$ lbs. per square inch.

We have, by substitution in formula (20),

$$l_3 = \cdot 0000247 \times f \times 40 \times 180 \times 900 = 160 \cdot f.$$

If in this we take $f = \cdot 03$ to $\cdot 05$ for perfect lubrication, we have

$$l_3 = 4 \cdot 8'' \text{ to } 8''.$$

If we take $f = \cdot 08$ to $\cdot 10$ for imperfect lubrication, we have

$$l_3 = 12 \cdot 8'' \text{ to } 16''.$$

The results show the great advantages arising from constant oiling of bearings.

As a practical application under the most trying conditions, we find that Messrs. Wm. Sellers & Co. are able to double the speed of their bolt cutters when an oil pump is used, without injury to the dies.

NOTE.—If for locomotive crank pin journals we assume N the number of strokes per minute $= 600$.

P the pressure per square inch in lbs. $= 150$, the formula (20) being changed to

$$l_3 = \cdot 00000247\, f\, P\, N\, d^2,$$

by removing the decimal point one place to the left, will give the length of journal commonly assumed in successful practice, if we assume the coefficient of friction at $\cdot 06$.

The above formula then becomes

$$l_3 = \cdot 013\, d^2.$$

This formula would show the amount of heat per square inch of projected area conveyed away from the crank pins of locomotives to be ten times greater than in the case of marine engines, did not the variations of speed and frequent stoppages of a locomotive prevent comparison.

Example:

Let $d = 18$ inches.

We have,

$$l_3 = \cdot 013 \times 324 = 4 \cdot 21 \text{ inches.}$$

We will next take up the diameter of the crank pin journal.

It is necessary, first, to determine its length by formula (20), and with this length to determine the proper diameter.

Let a = the deflection of pin under stress in inches.
Let S = the stress on pin in lbs.
Let E = the modulus of elasticity of wrought iron = 28000000 lbs.
Let W = the measure of the moment of flexure of the pin.
Let l_3 = the length of journal in inches.

The deflection of a beam fixed at one end, and loaded at the other ("Weisbach's Mechs. of Eng.," Sec. IV, Art. 217), is

$$a = \frac{S l^2}{3 W E}$$

If, again, the beam be supposed to be uniformly loaded and fixed at one end, its deflection will be (W. M. E., Sec. IV, Art. 223)

$$a_2 = \tfrac{1}{8} \frac{S l^2}{W E},$$

and if for the load at the end we concede a deflection of $\frac{1}{100}$ of an inch, we have for the same load under the two cases above mentioned,

$a_1 = \cdot 01$ inch,
$a_2 = \cdot 0038$ inch.

Then taking the most unfavorable case, *i. e.*, the load at the end, we have,

Letting $S = \frac{\pi d^2}{4} P_b$,

Letting P_b = the greatest pressure of steam in cylinder = the boiler pressure,

Letting $W = \frac{\pi d_3^4}{64}$,

$$\tfrac{1}{100} = \tfrac{1}{3} \frac{\frac{\pi d^2}{4} P_b l_3^3}{\frac{\pi d_3^4}{64} 28000000} = \frac{16 P_b l_3^3 d^2}{84000000 d_3^4}$$

$$d_3^4 = \frac{1600}{84000000} P_b l_3^3 d^2 \quad . \quad . \quad . \quad . \quad . \quad (21).$$

$$d_3 = \cdot 066 \sqrt[4]{P_b l_3^3 d^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (22).$$

Example:

Let $P_b = 60$ lbs. per square inch.

Let $l_3 = 8$ inches.

Let $d = 30$ inches.

Substituting in formula (22) we have

$$d_3 = \cdot 066 \sqrt[4]{60 \times 512 \times 900} = 4 \cdot 79 \text{ inches.}$$

There is no need of an investigation of the strength of a crank pin, as the condition of rigidity gives a great excess of strength.

The length of a steel crank pin is just the same as that of a wrought iron pin, and the modulus of elasticity of steel is so nearly equal to that of wrought iron, as to make formula (22) serviceable for both steel and wrought iron alike.

Referring to the table, we find the average pressure per square inch of projected area to be about 500 lbs.

If now we divide the whole pressure upon the crank pin by 500, we obtain the projected area required when this limit is not to be exceeded.

The equation $d_3 l_3 = \dfrac{\pi d^2 P}{4 \times 500}$ gives $d_3 = \cdot 00157 \dfrac{d^2 P}{l_3}$.

Example:

Let $P = 40$ lbs., $l_3 = 8''$, $d = 30''$,

$$d_3 = \cdot 00157 \frac{900 \times 40}{8} = 7 \cdot 06 \text{ inches.}$$

This latter method is perhaps the most practical, and has the advantage of limiting the pressure. It will almost always give larger results than the preceding method.

For journals in general,

Let R = force on bearing in pounds.

Let l = length of bearing in inches.

Let d = diameter of bearing in inches.

Let T = the number of turns per minute.

Let f = the coefficient of friction.

And we have

$$49908 = \pi T d \cdot f \frac{R}{l d},$$

$$l = \frac{\pi}{49908} f T R = \cdot 000063 f T R,$$

giving the minimum length of bearing allowable, which should always be exceeded where circumstances will permit.

WATER SUPPLY OF THE STATE OF NEW JERSEY.

Report by the Committee on Water Supply, read at Meeting of N. J. State Sanitary Association, held at Princeton, Oct. 17th, 1877.

By Albert R. Leeds, Chairman.

[Continued from Vol. lxxv, page 199.]

An important subject of inquiry in relation to the causes which may affect the taste and the wholesomeness of drinking-waters, was brought into prominence, by the excessive mortality, during the early part of June of this year, among the fish in the Passaic. Numerous articles, calculated to alarm the inhabitants of towns using Passaic water, were published by the local press, and also in New York. It was stated that thousands of fish had fallen victims to disease of an epidemic character, and the number of those perishing would suffice to contaminate the water; while the probability was that the same agencies which made the water fatal to fish, would render it detrimental to human beings. Many explanatory theories were advanced, such as the washing into the rivers of Paris green, used to arrest the ravages of the Colorado beetle. Some attributed it to the use of arsenical or other poisonous dye-stuffs, by establishments at Paterson, or the introduction of unusual amounts of manufacturing refuse, waste acids, alkalies, or other chemicals. The latter was the favorite theory, and received support from persons who had presumably examined somewhat into the matter.

I made two visits to Paterson, during the progress of the epidemic, and spent several days in collecting information. Both banks of the river, as far down as the Dundee dam, and up to Little Falls, were examined. Unfortunately, the height of the epidemic had passed when newspaper attention was attracted, and circumstances had intervened which apparently had removed the exciting causes. I saw, however, sufficient dead fish, in advanced stage of decomposition, to render it probable that the mortality might not extravagantly be estimated by thousands. No naturalist appears to have critically examined into the nature of the fish-disease.

Valuable information, however, is contained in the following letter, in reply to certain inquiries addressed to him, from Mr. John C. Roe, Fish-Warden at Paterson: "The epidemic in the Passaic River

began about May 26th, 1877, and ended June 14th. In the year preceding, there was no noteworthy exhibition of disease, but in 1875, it prevailed about one month later, in a much milder form than in 1877. Previous to this, nothing of importance had come to my notice, except an occasional dead sucker or mullet. These are to be found in almost any of our waters during the months of July and August, and are killed by what we term a blood-sucker, which attaches itself to the caudal fin. The epidemic this year was traced as far as Hanover, and to Peckman and Pequannock Rivers, which are headwaters of the Passaic. I visited Budd's Lake in Morris Co., and also Hopatcong and Stanhope reservoirs, and found the same disease, only in a very mild form.

"The species of fish affected, named in the order of their mortality, are as follows:—Sucker, mullet, chub, roach, sun-fish, yellow perch, cat-fish, and a few pickerel. In almost every case, diseased fish were found in the stomachs of the yellow perch and pickerel, and had probably caused their death.

"The disease appeared to attack the back-bone of the fish just below the head, and extend to the tail, the flesh decaying along the bone. In its last stages, red blotches or spots appeared on the fish, and were quickly followed by death. According to my observations, death ensued about 5 days after the fish were attacked. In the places where the disease most prevailed, the water varied in depth from 3 to 8 feet. The water was unusually low during the epidemic, in fact, lower than I ever recollect it to have been at that season of the year, and the mercury generally stood at 90° during the day, and from 65° to 80° during the night. My opinion is that the extremely warm weather, and the extremely low condition of the river at that season, caused a rapid growth of vegetable life, and the purging of the water, brought about by the above extremes, caused the vegetable matter to decay and produce a poison.

"The New York papers, the *Herald*, *Tribune*, and *Sun*, have each claimed to have discovered the cause. The *Tribune* finds it in the refuse matter coming from the factories in Paterson and vicinity, and asserts that the fish infected with the disease move up stream to get to pure water. I should like to know how they got over Passaic Falls, also the dam above the Falls, also Beatties' dam at Little Falls, 4 miles above Paterson. The *Herald* attributes the disease to the same cause, but goes only as far as Passaic City, 4 miles below Paterson.

The *Sun* claims that the locusts, which appeared in large quantities, were eaten by the fish, which were poisoned by them. But it is a well-known fact, that where the locusts were the most plentiful, no traces of the epidemic could be found. The fish affected, moreover, were not fish that feed on locusts, but fish that feed entirely from the bottom. I experimented with fish in the first stages of the disease, by giving them a bath of strong salt water, and then placing them in pure water. I found that a number recovered. I have also noticed a great many fish that have only one eye, and occasionally find one that appears as black as tar. I think they are fish that have recovered. My belief during the epidemic was that the first rain sufficient to raise the water 6 inches, would purify the atmosphere and water, and terminate the trouble. After the first rain no traces of the epidemic could be found. The sex of fish destroyed was about five female to one male. I have examined a number of fish taken from Croton reservoir this season, and found, in most every case, death was caused by blood-suckers."

The physical circumstances, important to note, are: that, prior to the epidemic, there had been a period of exceeding drought; less water, I was informed by Mr. Fowler, the President of the Society for the Promotion of Useful Manufactures, going over the dam at Paterson, than ever before at the same season. The heat, moreover, both in intensity and in duration, had been excessive and unusual. These circumstances appear to have combined, to increase the operation of agencies inimical to the fish-life in streams, which in all years operate to a certain extent, but seldom to produce an alarming mortality. The low water and warm weather, noticeable at these times, were accompanied by the appearance of unusual amounts of aquatic plants of a low order of vegetable life. From these circumstances, it appears that the following hypotheses are reasonable:

1. That the rapid development of vegetable growth may be attended with the production of vegetable organisms, which act as specific poisons upon fish-life.

2. That their decay, assisted by the intense heat of the sun falling upon areas covered by slight depth of water, results in a disintegration, by which they are diffused through the water, and, by means of the gases evolved by their decomposition, are floated to the surface. The organic impurities of a vegetable origin thus suspended in, or dissolved by, the water, may possibly be sufficient to originate disease.

3. The supply of dissolved oxygen may, by the operation of these causes, be lowered to such a point that it becomes incapable of supporting life among certain species of fish. In the first place, the oxidation of impurities and finely divided vegetable and animal matter, requires a large amount of oxygen. The covering of the river surface by floating algæ, would retard that aeration which is always taking place at the surface of a flowing stream. The stream would not be in receipt of that highly aerated water which flows into it from brooks and tributaries, descending from higher levels, or of air brought down by rain. Along with this exhaustion of oxygen, there would be a corresponding increase in the amount of dissolved carbonic acid, and of marsh gas, or even oily homologues of the marsh gas series, generated by the decay, under water, of vegetable matters, and now enormously increased in amount by the small depth of water covering.

Either one of these three causes, or all combined in varying proportions, might reasonably be regarded as efficient to produce the mortality witnessed. As a fact, with regard to the first cause, or organisms produced in waters and acting as specific fish poisons, little as yet is definitely known. The second hypothesis, that the mortality is due to decaying vegetable matters disseminated through the waters in excessive amounts at certain seasons, is advocated by many pisciculturists. The third, or deoxidation theory, is not without plausible grounds of support. Moreover, no complaint was made either of the appearance, taste, or odor of the water.

It is evident from the foregoing that there is urgent need, and immediate practical use, of more precise knowledge concerning the mutual dependence of plant- and fish-life in river water, and their relation to its condition of aeration.[1]

A beginning appears to have been made in this direction, by the examination of the water supply of New York and Albany, when contaminated by vegetable matters, some account of which will be found in the report of the Water Board of the former city for 1859, and in that of the latter, for 1865. In the former report, Prof. John Torrey attributed the musty odor and unpleasant taste, which characterized the Croton water during the month of August, 1859, to the

[1] For description of algæ, see "History of the Fresh Water Algæ of the United States," Prof. H. C. Wood, published by Smithsonian Institution.

rapid development of a bright green vegetable substance, diffused through the water and accumulated in large amounts on the surface of Croton Lake and elsewhere. The water in the lake at the time was very low, only a small portion going over the dam. Dr. Torrey says: "I think we are warranted in concluding that the recent offensive condition of the Croton water was owing to a rapid and abundant growth of a microscopic, conferva-like plant, which abounds in a volatile, odorous principle, soluble to some extent in water." This plant, Dr. Torrey referred to the genus Nostoc. He moreover thought it probable that it occurred more or less every summer, but only occasionally, by excessive growth, communicated an offensive odor and taste to the water, and was thus brought into popular notice. Even in this case, he did not believe that it communicated any unwholesome quality to the water.

Quite recently, during the summer of 1876, the water supply of Boston becoming deteriorated, Prof. Nichols, of that city, was requested by its Board of Water Commissioners to examine into the sources of the trouble. It had been previously noted that in the months of October and November, 1875, the drinking-water of the city of Boston had a taste resembling that of cucumbers. A similar taste, it is said, had been noticed as far back as the autumn and winter of 1854. When the taste reappeared in 1875, an examination of the water was made by Prof. W. R. Nichols, Mr. Edward Burgess, and Prof. W. G. Farlow, to ascertain whether any substance known to chemistry, zoology, or botany, could have produced the peculiar cucumber taste. They reported that no assignable cause could be discovered, but that, as far as the botanical examination showed, the water was unusually pure; that from the Bradley basin, where the cucumber taste was strong, being decidedly more free from vegetation, whether living or dead, than that from the Brookline Basin, where the taste was not perceptible.

"It has long been believed," Prof. Farlow remarks,[1] "that the algæ known as nostocs have a disagreeable odor, and, in many cases where unpleasant odors have arisen in bodies of water which serve as water supplies, it has been considered a sufficient explanation to say that the odor is produced by some nostoc-like plant, without, however, going so far as actually to find the plant which is supposed

[1] Bull. Bussey Institute, January, 1877.

to be a nostoc. Undoubtedly, the most disagreeable odor ever found in fresh water, may be produced by nostocs, using that word to designate the order Nostochiniæ, but by no means all the disagreeable odors and tastes arise from that source. As to the cucumber taste, there is not the slightest proof that it is caused by any algæ, either living or decaying.

"As far as smells are concerned, our knowledge is more complete. It is known that, when living, different species of nostoc may produce two different kinds of disagreeable odors: first, an indescribably suffocating odor, as in the case of several Lyngbyæ and Oscillariæ; and secondly, a sulphurous odor, as is given off by species of Beggiatoa. A still more disagreeable odor, resembling that of a pig-pen, is given off by species of nostoc in decay. These are Oscillaria, which appear as bluish-green masses growing on the mud or in shallow water.

"The algæ which exhale sulphurous odors belong to the genus Beggiatoa, which resembles Oscillaria in consisting of filaments endowed with motion, but which differs in color, being whitish, the cells being full of opaque granules. They look to the naked eye like white films covering decaying algæ and other plants. It has been shown, by Cramer, that the dark granules in species of Beggiatoa consist of sulphur. When Beggiatoa filaments are heated, the granules fuse into large yellowish drops and a sulphurous smell is developed."

In the summer of 1876, the trouble was particularly noticeable in the waters of Horn Pond, the head-waters of what is known as the Mystic Basin, which supplies Charleston and East Boston. "It was stated that a disgusting odor, said to resemble that of a pig-pen, had appeared in several portions of the pond, and it was found that a quantity of a plant called eel-grass had been washed ashore, and upon it was a slimy mass from which the odor seemed to proceed. This so-called eel-grass was not the flowing plant generally known by that name, the Vallisneria Spiralis, but a new species of Plectonema, of the order Nostochiniæ. It grew in great abundance at the head of the pond where the water was shallow, attached to other plants and sticks, and spread over the surface in areas of several square feet, forming blackish-green patches. Where the Plectonema was free from the slimy substance, it emitted the suffocating smell of many of the Oscillariæ, but was devoid of the pig-pen odor.

"In various places along the edge of the pond, and in some places where the Plectonema came to the surface, were masses of slime, at first of a pale bluish-green, afterwards of a brownish color, and emitting a most disgusting odor. This slime was composed of an amorphous mucus, made up of aggregations of decaying filaments, belonging to a species of Anabæna, or some nearly related genus, like Nodularia Litorea. It was shown by Dr. Bornet that the intensely disagreeable odor prevalent near Deanville, in Normandy, during August, 1874, was due to the decomposition of large quantities of the latter algæ.

"Early in October, the Anabæna had completely disappeared. Furthermore, the Plectonema, which, in August, was attached, was washed ashore in immense quantities, leaving the surface of the pond clear. A quantity of the Plectonema was kept for some time until it began to decay, when it began to give off the pig-pen smell, which could hardly have arisen from any remains of the Anabæna, as a microscopic examination showed no traces of it. It would seem then that the peculiar odor, which was so marked in the case of Horn Pond, may arise from decay of more than one species of the Nostochiniæ, and the probability is that a large number of species may produce it. The important point is that it is during their decay that the odor is found, not while they are growing. The question arises as to what killed the algæ so suddenly. Those living near the pond are ready to believe that it was the refuse from the tanneries, but there is no proof whatever that that was of a different character from what it had been previously, and the question is still open, why, at that particular time, the algæ were killed. It will be remembered that during the month of August, 1876, the heat was excessive, and the temperature of the surface water was raised considerably. We cannot doubt that the boiling rays of the sun had a destructive effect on the Anabæna, especially that which was caught in the meshes of the Plectonema, and, by the falling of the water consequent upon the drought, exposed on the surface.

"Some words, as to the remedies to be applied in similar cases, may be of service. If a sudden odor of pig-pen arises, it is, in all probability, owing to the decay of large quantities of some algæ of the nostoc family, and most probably one of the finer species diffused through the water. As the decay is generally, if not always, brought about by causes beyond human control, it is useless to try to stop it

when it has once begun. On the other hand, there is no occasion for great alarm; for when they have once begun to decay, algæ like Anabæna disappear in a few days. Knowing that floating algæ are caught in the meshes of Plectonema and similar filamentous algæ, and thus during the sinking of the water, which usually occurs in July and August, exposed on the surface to the direct heat of the sun's rays, which cause them to decompose, it is evident that it is a useful precaution to remove, as far as possible, the long filamentous algæ and fine-leaved phanerogams.

"There is another plant which forms a bluish or yellowish-green scum on the water, often spread over a considerable area. Were it not that it forms such a thin layer, it could be collected in large quantities. Kept in bottles, it multiplies and forms irregular masses of a pea green color and mealy consistency. At first solid, the superficial cells imbedded in a gelatinous mass increase rapidly, and it becomes hollow. Then certain portions project like buds, and finally separate from the mother plant which seems to be perforated. This plant, Clathrocystis Æruginosa, was described by Henfrey, and is now classed by Cohn among the Bacteria, and placed near Clathrocystis Roseo-persicina, a plant which forms purplish-red films on decaying algæ, and on the ground along our coast, and which in Europe is also found in fresh water, but it has not yet been found in the interior of our own country. We mention it from its frequent occurrence, and because it has been supposed to injure the water in some places. There is no account of any injury having been done to man; but in Germany, where it is known as the Wasserblüthe, it has been destructive to fishes. It has been suggested by Cohn, in his Berträge zur Biologie (Vol. I, Part III, p. 155), that the slimy substance of which it consists forms a coating over the fish, and shuts off the supply of air necessary to support life. Professor Hagen, of Cambridge, suggests, as a remedy, the introduction of snails into water where it occurs, as they are extremely voracious, and eat large quantities of fresh-water algæ."

These investigations concerning the fresh-water algæ, and their connection with and interdependence upon the animal life of streams and upon their dissolved oxygen, are of great importance. Upon them the solution of many unsolved problems of water-pollution and water-purification largely depends. The previous methods of dealing

with these problems are eminently unsatisfactory and inconclusive.[1]

It is stated above that the deterioration in river water is accompanied by the development of certain lower orders of vegetable life. Along with this, there appears to be a corresponding change in its fauna, and along with both, a diminution in the percentage of dissolved oxygen. It has long been supposed that dissolved oxygen played a great part in the purification of streams, and that it was the principal agent by which putrefiable substances were broken up and converted into harmless inorganic compounds. A recent essay by M. Gerardin, to which the prize was awarded by the Paris Academy of Sciences, contains some striking results. To summarize, his methods of inquiry were:

1. A determination of the amount of oxygen held in solution.
2. An observation of green plants and aquatic mollusks.
3. A microscopic examination of algæ and infusoria.

It is claimed that the results obtained by these three methods were identical, and that, where the water was clear, with abundance of fish, water-cress, etc., it contained a correspondingly large amount of oxygen; while in places where the dissolved oxygen was small, fish and the higher types of aquatic plants were wanting, and certain low forms of vegetable growth had taken their place. The river Vesle, in France, from Rheims to Braisne, was taken as the field of observation. It was studied over a distance of 37½ miles, during which it received the sewage of one large town (that of Rheims), amounting to 4,180,000 gallons, and other impurities. Above Rheims, the water (which was clear, wholesome, and with abundance of fish, charas, water-cress, iris, etc.) contained 1 cubic inch of oxygen in 100 cubic inches.

In passing through a suburb above Rheims, the Vesle received the refuse of some dye-works, which colored the water; and in place of the fish and water-cress, Sparganium Simplex made its appearance. At a point where the water had received the contents of the five principal sewers of Rheims, the water was thoroughly polluted and contained but ·05 cubic inch of oxygen in 100 cubic inches. Two species of algæ, the Beggiatoa Alba and the Oscillaria Natans, were developed largely, the latter to such an extent, that the whole surface of the sluggish water was covered with a thick blackish coat.

[1] See article entitled "Recent Progress in Sanitary Science," *American Chemist.*

This coat was seemingly so solid, that animals, and even men, ventured upon it, mistaking it for terra firma. Above the mill at Macan, where the oxygen had increased to 0·74 cubic inch, the two varieties of algæ mentioned above had disappeared, and the bed of the Vesle was covered with a long, whitish alga, called Hypheothrix. At Compensé mill, the oxygen had increased to 0·8 cubic inch, the Hypheothrix had almost completely disappeared, and the Sparganium Simplex was again abundant. Below this point the amount of oxygen increased, and with it a corresponding change took place in the vegetation until, at Braisne, the water contained 1 cubic inch of oxygen per 100 cubic inches, all traces of pollution had disappeared, and fish and water-cress flourished. From this it would appear that a properly aerated and pure water showed, when polluted, the amount of pollution by a corresponding diminution of oxygen, by the appearance of Sparganium Simplex, Spirogyra, Hypheothrix, Beggiatoa and Oscillaria, and progressive improvement by a corresponding increase of oxygen, and the appearance of these plants in reverse order.

In view of the preceding facts we think that there ought to be as certain reform in the method of examining into the potability of water supplies. In the larger number of cases the great expenditure of labor upon the percentage determination of the mineral constituents, which are generally small in amount, except in turbid streams containing much earthy matter in suspension, or in springs deserving the appellation of mineral- rather than of drinking-waters, might be omitted. The estimation of the constituents upon which the hardness depends, relates to their employment for household and manufacturing purposes, and is not connected with our present inquiry. The time thus saved might be expended in making *comparative* determinations of the water under examination, at a point *above* where it can be suspected of having received contamination, and *after;* of the chlorine, nitrous and nitric acids, dissolved oxygen, etc., and generally of those constituents whose determination is essential to the main question. Furthermore, while admitting the great value of the "ammonia" and "albuminoid ammonia" processes in many cases, as in the determination of the contamination of wells by sewage, yet there is much reason for believing that an organic analysis of the residue affords a safer ground of comparison. These points, however, require further investigation.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.

By Robt. Briggs, C. E., Cor. Mem. Am. Inst. of Architects, etc.

In continuation of the paper read before the American Institute of Architects,[1] which has appeared in the three previous numbers of this Journal, it is desirable to support the argument for the impracticability of attaining the full summer condition of humidity, for air in winter which has been warmed to the temperature of comfort, by more extended computations than could be presented to an audience, or brought within the scope of comprehension of the listener or the casual reader. The single example with specified relations, which was taken, showed, on calculation, that nearly as much heat would be expended in supplying vapor for the usual hydration of air of usual humidity and of 34° temperature (which air was heated to 70°), as was expended in heating the air itself.

The temperatures, and humid condition of about 69 per cent. assumed, being the averages of nature, out of doors, for three warm or three cold months, in the city of Philadelphia, in 1844, as reported by Prof. Bache. It occurs, accidentally, that the exact conditions of temperature and humidity chosen for an example, give the ratio of heat demanded for the two purposes incident to warming air as unity, while this ratio, for other temperatures and degrees of humidity, will be found to vary materially. For the purpose of exhibiting more completely the general case, the accompanying table has been prepared to show what quantities of heat are demanded for heating, or are given out in cooling air of 70 per. cent. humidity, from various temperatures (from 0° to 100°) to 70°, in direct comparison to the quantities for vaporization or condensation of water to procure the condition of 70 per cent. humidity to the air of 70°. When 70° and 70 per cent. humidity may be accepted as the American summer condition of comfort for the air; it being asserted that 70°, with 80 per cent., or more, of humidity, is close and enervating, while 70°, with 60 per cent., or less, of humidity, is fresh and cool, and demands heavy clothing to preserve the comfort of the individual—a proper and necessary demand in winter.

[1] At the Meeting of the Institute at Boston, October 18th, 1877.

TABLE.

VOLUME AND WEIGHTS OF AIR AND VAPOR OF HUMIDITY—TEMPERATURES OF SATURATION AND DEW POINT—HEAT TO BE EXPENDED IN WARMING OR COOLING AIR OR VAPOR TO THE TEMPERATURE OF 70° FAHRENHEIT AND CONDITION OF 70 PER CENT. HUMIDITY.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.
Temperatures in degrees Fahrenheit.	Volume of dry AIR to one Pound. Barometer 29·922 inches.	Weight of dry AIR per 1000 cubic feet. Barometer 29·922 inches.	Force of VAPOR in inches of Mercury Column.	Weight of VAPOR in 1000 cubic feet = quantity of Vapor in saturated Air.	70 per cent. of weight of VAPOR in 1000 cubic feet = quantity of Vapor in air of 70 per cent. humidity.	Weight of 1000 cubic feet of AIR of 70 per cent. humidity, including its vapor. Barometer, 29·922 inches.	Weight of dry AIR in 1000 cubic feet of Air of 70 per cent. humidity. Barometer 29·922 inches.	Weight of VAPOR accompanying 73·63 lbs. of dry air at given temp., and 70 per cent. humidity. Barom., 29·922 in.	Percentage of volumes of AIR of 70 per ct. humidity displaced by the presence of aqueous vapor. Barom., 29·922 in.	Temperature of Saturation in degrees Fahr. = Dew Point of AIR of various temperatures, and 70 per ct. humidity.	Temperature of indication of Wet Bulb Thermometer, taken from Glaisher's tables.	Weight of VAPOR to be supplied or taken from 1000 cu. ft. of Air, when brought to 70° Fahr. to make quantity needed for 70 per cent. humidity.	Heat units for warming or cool'g 0·07363 lbs. of AIR with its accompanying vapor from given temp. to 70° Fahr.	Heat units demanded for vaporization or condens. of vapor to give 70 per ct. humidity to one cu. ft. of AIR of 70° F.
0	11·577	86·38	0·045	0·081	0·057	86·35	86·29	0·048	0·11	.....	.....	0·749	1·228	0·797
5	11·704	85·44	0·054	0·095	0·067	85·40	85·33	0·058	0·13	.....	.....	0·739	1·141	0·787
10	11·830	84·53	0·067	0·118	0·082	84·48	84·40	0·072	0·16	1·1	8·8	0·725	1·054	0·772
15	11·957	83·64	0·085	0·148	0·104	83·58	83·47	0·092	0·20	7·3	13·9	0·705	0·966	0·751
20	12·083	82·76	0·108	0·186	0·130	82·68	82·55	0·116	0·25	12·4	18·9	0·681	0·879	0·725
25	12·210	81·90	0·136	0·232	0·162	81·80	81·64	0·146	0·32	17·2	23·5	0·651	0·792	0·693
30	12·336	81·06	0·169	0·285	0·199	80·94	80·74	0·182	0·40	21·8	27·7	0·615	0·704	0·655
32	12·387	80·73	0·183	0·308	0·216	80·60	80·38	0·198	0·43	23·6	28·8	0·599	0·670	0·638
35	12·463	80·24	0·207	0·345	0·242	80·10	79·85	0·223	0·49	26·5	25·	0·574	0·617	0·611
40	12·590	79·43	0·251	0·415	0·290	79·26	78·96	0·271	0·59	30·8	30·1	0·526	0·529	0·560
45	12·716	78·64	0·302	0·494	0·346	78·43	78·08	0·326	0·71	35·5	34·6	0·471	0·432	0·501
50	12·843	77·87	0·362	0·587	0·411	77·62	77·21	0·392	0·85	40·3	45·	0·405	0·353	0·432
55	12·969	77·11	0·433	0·695	0·487	76·82	76·33	0·470	1·01	45·1	49·	0·328	0·266	0·349
60	13·096	76·36	0·517	0·821	0·575	76·02	75·44	0·561	1·21	50·0	54·	0·236	0·178	0·251
65	13·222	75·63	0·616	0·968	0·678	75·22	74·54	0·669	1·44	54·9	58·5	0·127	0·088	0·136
70	13·349	74·91	0·732	1·138	0·797	74·43	73·63	0·797	1·71	59·8	63·	0·000	0·000	0·000
75	13·476	74·21	0·867	1·336	0·935	73·65	72·71	0·946	2·03	64·7	68·	0·149	0·090	0·159
80	13·602	73·52	1·023	1·562	1·094	72·86	71·77	1·121	2·39	69·5	72·5	0·324	0·181	0·345
85	13·729	72·84	1·203	1·822	1·275	72·07	70·80	1·326	2·82	74·2	77·5	0·529	0·272	0·563
90	13·855	72·17	1·410	2·117	1·482	71·28	69·80	1·563	3·30	78·9	82·5	0·766	0·365	0·816
95	13·982	71·52	1·647	2·452	1·716	70·49	68·77	1·837	3·85	83·7	87·5	1·040	0·460	1·108
100	14·108	70·88	1·918	2·828	1·980	69·69	67·71	2·152	4·49	88·4	92·5	1·355	0·556	1·443

The figures relating to weights in the foregoing table, refer to 1000 cubic feet (a cube of 10 feet side) for a unit, to avoid the repetition of 0's in decimals; by multiplying any value by 7, the weights per cubic foot in grains will be found. All the weights are in pounds avoirdupois and decimals. The volumes are in cubic feet.

Columns II and III are derived from Regnault's data; weight of one cubic foot of dry air = 0·080728 pound = 12·387 cubic feet per pound; and rate of expansion = 0·002039 volume for each degree Fahrenheit from 32° = 0·025315 cubic foot per pound from 32°.

Column IV is taken from Guyot's tables, Regnault's data, slightly corrected by differences.

Column V is derived from $W = \frac{0{\cdot}622}{29{\cdot}922} \times$ value of Column III $\times$ value of Column IV, where 0·622 = specific gravity of vapor in air of the same tension; and 29·922 = inches of mercury column which measures the tension of air in Column II.

Column VI is obtained directly from Column V, as indicated in caption.

Column VII is obtained by taking the difference of weight of the volume of vapor in the air, from that of the air which it displaces, and deducting their difference from the respective values in Column III. The values in Column VII agree as closely as could be expected with results in Glaisher's tables.

Column VIII is obtained by deducting weight of vapor, Column V from Column VII.

Column IX is obtained by taking the ratio of quantity of dry air in the several values of Column IX, with the value at 70° (= 73·63 pounds) as a unit, and dividing by this ratio the values in Column VI.

Column X is obtained by taking 70 per cent. of $\frac{F}{29{\cdot}922}$, where F is the tension of vapor possible to exist at the given temperature, as given in Column IV, and 29·922 is the tension of the atmosphere. It should be noticed that this column has its units in percentages: the first value, for instance, is $\frac{11}{100}$ of a per cent.

Column XI is obtained by making a computation of three columns for saturated air, like VII, VIII and IX, and thus ascertaining at what degree of temperature the values in Column IX coincide with those in the same column for saturated air. This column closely agrees with Glaisher's, varying two degrees higher at 15° and corresponding at 80°.

Column XII is taken from Glaisher's tables at 70 per cent., and is sufficiently exact for use.

Column XIII is obtained by taking the difference between the quantity of vapor in air of 70° Fahrenheit, and that in the several values given in Column IX.

Column XIV is obtained by multiplying 0·07363 pounds (the quantity of dry air in a cubic foot of air of 70° Fahrenheit and 70 per cent. humidity) by 0·238 (the specific heat of air), adding to this value, that of the amount of the several values in Column IX, multiplied by 0·475 (the specific heat of vapor), and then multiplying the sums of the above by the number of degrees from 70° which the air is to be heated or cooled.

Column XV is obtained by multiplying the values of Column IX (the vapor to be supplied or removed) by 1065° = the latent heat of steam from and at 70°, and dividing the result by 1000, so as to give the heat of vaporization belonging to one cubic foot of air at 70°.

A careful study of the table, with comparisons of the values given in the several columns, will readily allow any student to find the fullest corroboration of the views expressed in the original paper; but for the convenience of the general reader, it may be well to exhibit some of the results. Thus, calling attention to Column XI, it will be seen that the air of saturation at 60° becomes, by heating, that of 70° and 70 per cent. humidity; showing a close approach of English and American humid conditions to the comfortable condition in either case. Again, the temperature of saturation for air of 80°, with 70 per cent. humidity, is 69·5°; consequently, air of above 80° of the usual humid condition of our climate in summer, will become a mist and rain, unless its moisture be absorbed by some non-heat-giving absorbent. If such air is to be reduced to the 70° standard of comfort, by means of surfaces cooled by currents of water, such surfaces must have a temperature at least below 60°, and probably 10° below that point, to abstract, by condensation, the moisture from the air. The heat demanded for condensation, therefore, will be increased some 20° below that of cooling the air, but as the latent heat of vapor of water is nearly constant, the difference of quantity of heat for cooling is not materially changed.

A study of the last two columns will demonstrate that as the quantity of moisture present in air falls off much more rapidly than the temperature, the quantity which is requisite to make up the moisture in air at 70° and 70 per cent. humidity, from the condition at the various temperatures with the same ratio of humidity, becomes more and more nearly the same as the temperatures fall off. The great heat demanded for changing water into vapor accordingly, is nearly constant for the low temperatures, and the heat demanded for warming

air gains on that for vaporization of water; and after passing a greatest difference at between 55° and 60°, attaining an equality at about 36°, it becomes about one-half greater at 0°.

The tabular values here given have, it is thought, been first grouped together in this, or any form, and they will be found a ready and convenient basis for the application of the various meteorological conditions to warming and ventilation.

COMPARATIVE EFFICIENCY OF SCREW PROPELLERS WITH TWO AND WITH FOUR BLADES.[1]

The records of experiments in screw propulsion contain little to parallel the anomalous results obtained with the twin-screw dispatch vessel *Iris*. This ship was intended to attain a velocity of 17·5 knots an hour with 7000 indicated horse power. She was built on lines suggested by Mr. Froude, as the result of an elaborate inquiry into the laws of fluid resistance to floating bodies; and it was anticipated that every expectation formed concerning her would be realized. When she was tried on the measured mile for the first time, although her engines worked up to 6880 horse power, the ship reached a speed of but 16·45 knots; and as the speeds vary about as the cube roots of the powers, it was evident that a power of about 8250 horses was the least that would suffice to drive her at 17·5 knots an hour, which power could not be got from the engines. Much disappointment was felt, and various explanations were put forward to account for the shortcomings of the ship. It is generally known that twin screws are not on the whole so efficient as single screws, because they cannot be used without some arrangement to carry them outboard, either in the shape of wrought iron brackets or stern tubes, or both, and these appurtenances obviously increase the resistance of the ship. But for this Mr. Froude allowed in his calculations, or more properly speaking, it was assumed that the lines which he had laid down for the ship would prove so excellent that notwithstanding the presence of stern tubes, the *Iris* would steam as fast, power for power, with twin screws as if she had been fitted with one screw. We have seen that this theory was hardly supported by the earlier trials of the

[1] From the *Engineer*.

ship. It was also suggested that the screws themselves were in fault, and that they would prove more efficient with two blades each than with four blades. Little could be urged in favor of this theory. An eminent authority has stated that between the best and the worst formed screw there is not ten per cent. difference in efficiency, the pitch being the same. In normal practice it is known that propellers, whether they have four, three or two blades, are about equally good, and that the number of blades is settled as a rule by considerations which have little or nothing to do with efficiency, but refer to vibration and its prevention more than to anything else. To assert, therefore, that much improvement would be effected by taking two blades off each screw of the *Iris* appeared preposterous. Indeed, there was some reason to think that quite as much would be lost by augmented slip as could be gained in any direction. However, the experiment would cost very little, and so it was made, with, as we have said, results which are, we believe, without any parallel. The second speed trial of the ship took place on Friday, the 15th of February. We have already published the figures, but for convenience we reproduce them here—giving, for simplicity sake, only round numbers concerning the engines. On the first trial, the engines making 43 revolutions per minute indicated 768 horse power, and the speed of the ship was 8 knots. On the second trial, with 45 revolutions, and 604 horse power, the speed was 7·95 knots, or practically the same as on the first trial. Thus, 164 horse power was saved. On the first trial, with 65 revolutions, and 2561 horse power, the speed was 12 knots. On the second trial, with 65 revolutions, the power was 1661, and the speed 11·759. Here a loss of less than a quarter of a knot an hour was accompanied by a saving of as much as 900 horse power. On the first trial, with 82 revolutions, and 5210 horse power, the speed was 15·123 knots; on the second trial, with 81 revolutions, the power was 3335, and the speed 14·507 knots. Here we have a loss of ·616 of a knot, and a reduction of 1875 horse power. Finally, in the last trial, with 89 revolutions, and 4400 horse power only, a speed of 15·726 knots was obtained. As it was not considered advisable to run the engines faster than 89 revolutions per minute, the experiment terminated here. It will be seen that a velocity less by ·724 knot than that realized with four-bladed screws was obtained with the altered propellers, with 2480 horse power less. If

the two-bladed screws prove equally efficient, when their pitch has been altered from 18 ft. to something sharper—which will permit the engines to work up to a higher power without making more than 88 or 90 revolutions—the intended speed of 17·5 knots should be obtained with about 6200 indicated horse power, or, say, 2000 horse power less than would have been demanded by four-bladed screws.

An examination of the figures will show that the results are somewhat lacking in uniformity. Thus, if we take the first pair of experiments, it will be seen that very little, if any, advantage was gained. The speed with the two-bladed screws was slightly less than when four blades were used, and the power was also less. Setting the two against each other, it may be said that no advantage whatever was gained by the change; and had the experiment ended here —as it might very well have done had it been carried out with a cargo steamer instead of with what is intended to be the fastest ship in the British navy—it would have been taken as proved that there is nothing to choose between four blades and two blades. The facts are instructive, as showing how easy it is to draw erroneous conclusions from incomplete data. In the second series of experiments, the power with two-bladed screws was 1661 for a speed of 11·76 knots. Had the speed been 12 knots, the power would have been about 1750 horse power, so that the true saving amounts to 811 horse power. Here the gain is enormous, and, as we go on step by step, so does the benefit increase, and it thus becomes evident that what holds true of screws running at slow velocities, by no means holds good for screws revolving rapidly. Again, it will be seen that, notwithstanding the loss of one-half the propelling area of the screws, the slip was not increased to any serious extent. Thus, at 8 knots the engines made but two revolutions per minute more with the reduced screws than they did with the unaltered propellers. The slip was thus augmented 36 ft. per minute, or less than one-third of a knot per hour. At 12 knots the slip was but slightly augmented. Practically it may be said that no loss of any kind worth mentioning ensued from the change.

We are thus brought face to face with the fact that the four blades which were removed required nearly 2000 indicated horse power to work them, and we have to consider in what way this enormous power was expended. The problem is one far from easy of solution.

It is impossible to maintain that it was wasted in overcoming the surface friction of the propeller blades in the water. If that were so, then the remaining blades must continue to offer the same proportionate frictional resistance; and of the 4400 horse power actually exerted by the engines of the ship on her last run, nearly 2000 would be wasted, and only 2400 horse power net would be left for other resistances and for propulsion, which is absurd. In the runs when the speeds were nearly identical, the thrusts must also have been nearly identical. The efficiency of both the four-bladed and the two-bladed screws was therefore so far the same. The defect of the former lay in the fact that much more power was required to turn them than sufficed with the latter. It may be argued, perhaps, that this statement is not accurate, and that the four-bladed screws really exerted a much greater thrust than their fellows, but that they operated in some unexplained way to prevent the influx of water to the ship's stern, and so increased her resistance. We see no ground whatever for this theory. The only feasible explanation of the phenomena appears to us to be that which we have already stated—the screws were harder to turn round with four blades than with two blades. Why they were harder to turn is quite another point, which we are unable to determine with certainty, nor are we aware that any one else is in a better position. The problem deserves the most careful investigation, and we have no doubt it will receive it from Mr. Froude. But it is clear that the abnormal resistance did not materially affect the performance of the screw as an agent for giving a thrust. Yet if so much of the power had been wasted in what is known as "churning" the water, it seems probable that the thrust would have been diminished. On further examination we believe it will be found that the four-bladed screw was hard to turn, because it carried round with it a great deal of water. In other words, as it progressed ahead it continually imparted a motion of rotation to successive bodies of water previously at rest, or moving in easy curves or right lines. The two-bladed screw does not do this to the same extent, because it is deficient in what may be termed transverse or projected area. In other words, the power of the engines was wasted in putting water in motion in a direction not parallel with the keel, and this motion was useless as a means of producing thrust.

INCRUSTATIONS ON BRICK WALLS.

By William Trautwine.

The disfiguration of brick house fronts, by white incrustations, is now so general that it is to the interest of the public, and of brick-makers and builders particularly, that its causes shall be determined and a remedy applied, so that, if possible, houses built hereafter may be free from it. Many recent attempts at ornamental brickwork have resulted only in unsightly walls. The incrustation has been variously discussed in the newspapers, but owing to conflicting views of its causes, builders, brick-makers and bricklayers appear still to doubt the efficacy of any remedy hitherto proposed. It is desirable that all observed facts and statistics of attempted improvements should be collated and reviewed by some competent authority.

This defacement is most noticeable in dry weather on parts of walls subjected to dampness, and on entire walls after rain-storms have soaked them. North and east walls are coated on drying after north-east storms. Chimney walls and chimney tops, lines of leaky or obstructed water-spouts, spaces beneath window-sills, walls near the pavement, and pavement bricks, are especially marked. The white coating is derived primarily from both bricks and mortar, and in some cases it is difficult to decide, without dissecting the walls, whether the bricks, the mortar, or both, are or are not concerned. The Bankers and Brokers' building, opposite the Stock Exchange, is not yet completed, but its walls are already unsightly with white patches. The black mortar or cement with which they are pointed has disintegrated and crumbled out here and there, leading to the conclusion that this is chargeable with the defacement. The bricks, however, are coated where the pointing is not at all affected, and one particular brick, which was left out of the wall, and was faultless in form, color and consistency, showed white patches when it dried after having been wet.

It will be found most convenient to consider first, the incrustation as derived originally from the bricks. It is most conspicuous on comparatively new walls. It may be observed in the outskirts of the city, on very new walls of unfinished houses in which no fires have burned, and where the mortar is unchanged. In these cases the

white substance is dissolved by moisture from the bricks, which contain it before they are built into the houses. The writer has visited several brick-yards in the suburbs, where piles of new bricks, which had never been in contact with mortar, but remained in a comparatively pure atmosphere since leaving the kilns, showed the common white incrustation. Some of the bricks which remained in the kiln were also coated. In several yards the incrustation had, here and there, a yellow tinge, possibly from traces of oxide of iron or hyposulphite of lime. One of these bricks, taken hap-hazard, was examined somewhat in detail. The white coating had a peculiar taste, in which that of sulphate of magnesia (Epsom salts), though disguised, was recognizable. As this white substance had come out from within the brick, the latter was crushed and the debris digested in water. At the end of a week the water had dissolved out a mixture, consisting mainly of the sulphates of magnesia, lime and iron. This brick contained no traces of sulphites, soluble carbonates, or soluble chlorides. The white incrustation disfiguring several fine pressed bricks in a new wall was also examined. It had so saline a taste that most persons would have pronounced it common salt. Nevertheless it contained none. It was almost wholly sulphate of lime and magnesia, with traces of iron and alumina. No carbonates were present. Several other specimens of incrustation were examined, with the same results. Two specimens of incrustation were examined specially for soda and potassa, but neither contained noticeable quantities.

The fact being established that bricks burned with coal fires are impregnated with the soluble sulphates mentioned above, specimens of brick clay from the pits of different brick-yards were next examined, in order to determine whether, and to what extent, these salts originally exist in brick clay, or are produced when bricks are burned with coal fires. None of the specimens contained free sulphuric acid or appreciable quantities of soluble sulphates (such as the sulphates of magnesia, lime or alumina). They contained no soluble carbonate or chloride. Only minute quantities of insoluble carbonates (such as the carbonates of lime and magnesia) were present. Further examination proved that all the specimens consisted chiefly of clay proper, *i. e.*, silicate of alumina, with much oxide of iron, and small proportions of lime and magnesia, which, presumably, were also contained as silicates. The proportions of lime and magnesia contained in the clay—separated by long digestion with an excess of hot

sulphuric acid—about equaled those existing as sulphates in the aqueous brick solution; suggesting the inference that brick burning may, in some instances, convert all or nearly all the supposed silicates of magnesia and lime into sulphates.

The process of burning bricks with coal sufficiently accounts for this conversion. Nearly all coal contains diffused particles of sulphide of iron, or iron pyrites. These are decomposed when coal burns, and sulphurous acid gas is one of the products of the combustion. When sulphurous acid gas, air, moisture, and substances which have an affinity for sulphuric acid, are brought together at high temperatures, long sustained, sulphates of the susceptible substances are formed. The silicates of lime and magnesia are probably decomposed under these circumstances, sulphates of lime and magnesia being formed. while silica is liberated. It is, therefore, reasonable to suppose that when the dense, sulphurous vapors of a coal burned brick kiln, which are suffocating outside of it, are diffused, with moisture and air around and through the clay of intensely heated bricks for the greater part of a week, the fires being maintained usually three days, and the kilns opened at the end of a week, a reaction takes place; and that when the bricks are turned out from the kiln, they are impregnated with the above named sulphates. When the bricks become wet, these compounds dissolve, and in dry weather, succeeding storms, the solution evaporating from the surface of the bricks leaves them coated with these white compounds.

Sulphate of magnesia possesses the peculiar property of efflorescing, or blossoming, in dry air. In this way a very small amount becomes conspicuous. Brick clays contain varying proportions of lime and magnesia, and the percentage of iron pyrites varies in different specimens of coal. Bricks may be noticed apparently overstocked with the sulphates of magnesia and lime. These are much whiter in dry weather than others surrounding them. Coal is now generally, if not universally, used here for brick burning in place of wood. Coal dust is commonly mixed with brick clay in clay pits, and may add to the production of sulphates within the bricks. The white incrustation, however, occurs on bricks in yards where coal dust is not mixed with the clay. It is not used in pressed bricks, and these are as frequently defaced as others. Common bricks, in back buildings, are coated with the white incrustation, but generally escape attention. Bricks least subjected to sulphurous vapors while burning, may

be less impregnated with the sulphates of magnesia, etc., than others.

The simplest way to get rid of the sulphates, so far as the bricks supply them, is to avoid producing them while manufacturing the bricks. Pressed bricks and others intended for ornamental purposes might be burned with wood or with coke, if free from sulphur, in separate kilns far away from places where coal is burned in considerable quantities. Unless afterwards exposed to an unusual amount of sulphurous vapor, they would probably undergo no change.[i]

It has been asserted that the white coating was formerly noticed on bricks burned with wood, but the evidence appears to be mostly the other way. It is quite possible, though, that a white efflorescence, derived from the mortar, may have been observed on old wood-burned bricks; or that such bricks in rare instances have been specially subjected to sulphurous vapors, and thus altered.

It has been suggested that the white incrustation results from chemical change effected in bricks by sulphuric acid vapors in the air—derived from coal burned as fuel and from the combustion of illuminating gas. If the gas is properly purified at the gas-works, little sulphuric acid can be traced to it. Much more is generated by burning coal in houses and factories, but it is at least doubtful if much change is effected by it in bricks, particularly after its diffusion, though there is no doubt of its effect, in time, upon mortar, as explained hereafter. We have seen that bricks now generally contain enough of the unwelcome sulphates before they are placed in walls, and that, in some instances, all the susceptible magnesia and lime in them are then already converted into sulphates. The small amount of sulphuric acid diffused in the air is insufficient to produce any effect until after long exposure, yet new bricks are more disfigured than old ones. Silicates of lime and magnesia in the semi-vitrified bricks are somewhat protected from the action of the air. It is questionable, on the principle of elective chemical affinity, whether these silicates, even if more exposed, would undergo decomposition in the presence of the more vulnerable mortar. Some bricks, however, may contain free lime and magnesia.[ii] If the atmospheric acid vapors affected silicate

[i] Clay sometimes contains iron pyrites, and its decomposition results in the formation of sulphates. Such clay is, of course, unsuitable for bricks intended for house fronts.

[ii] The writer does not assert that the magnesia and lime found by him in the clay specimens existed as silicates. This point was not determined, and is assumed only because no carbonates or sulphates of magnesia or lime were found in the clay.

of magnesia in bricks, serpentine stone fronts—almost wholly silicate of magnesia—would be much more affected. Many of these have been carefully examined, but in no case were the stones altered. Sometimes, the thick lines of mortar between them being decomposed, solution of sulphates from these had washed over the stone-work and defaced it.

Sulphate of magnesia is largely produced by the decomposition of mortar. Most of the lime used here is burnt from magnesian limestone, obtained in this vicinity, and the result is a mixture of lime and magnesia in varying proportions. The limestone belt of Chester Valley, which runs diagonally across the State, and which furnishes most of our lime, is largely magnesian limestone; the lower sub-division of the same formation in New Jersey being specially named the magnesian limestone in New Jersey geological reports. The mixture of lime and magnesia thus obtained, when slaked and made into mortar, is very susceptible to the influence of sulphurous fumes. These react, forming the sulphates of lime and magnesia. The great solubility of sulphate of magnesia facilitates its diffusion, and makes it the chief cause of defacement; sulphate of lime being comparatively insoluble. As the sulphate of magnesia dissolves and effloresces, the mortar is disintegrated. Sulphurous acid from coal burned in houses, produces its chief effects before it is diffused in the outer air. As it passes up through a chimney, it finds its way through crevices and pores in the wall, and thus directly attacks the mortar; sometimes causing the fall of chimneys, by eating out the mortar cementing them. The bricks, when damp, absorb sulphate of magnesia, or sulphate of magnesia and lime, from the altered mortar surrounding them. Sulphate of magnesia from altered mortar is most noticeable within doors, on chimney walls and in cellars, where the damp mortar is directly subjected to sulphurous vapors. Efflorescent crystalline masses of sulphate of magnesia often accumulate and protrude from between the loosening bricks.

Dampness produces a solution, which is sometimes diffused through a brick and makes its appearance outside, while the outer lines of mortar bordering the brick remain intact.[1] Several soft bricks in the outer wall of a chimney flue were examined recently. They were completely impregnated, as well as coated, with a white substance,

[1] Bricks readily absorb solutions, such as those of common salt, soap, etc., and these substances appear on the surface when the solutions evaporate.

which had disintegrated some of them, and which, on analysis, proved to be sulphate of magnesia, with traces of lime, alumina and oxide of iron. Sometimes, after long exposure, the outer lines of mortar appear to be directly affected by sulphuric acid vapors diffused in the surrounding atmosphere. Delicate crystals and protuberances of sulphate of magnesia and washings from these were observed on mortar lines in brick and granite garden walls, as well as on house fronts. Thick mortar lines in walls of brown stone buildings are much affected. Churches at Thirty-sixth and Chestnut Streets, Eighteenth and Columbia Avenue, and Franklin Street near Brown, will serve as illustrations. The Syenite retaining walls enclosing the Friends' Meeting House, at Seventeenth Street and Girard Avenue, and those of the House of Refuge on Poplar Street, show the defacement. In all these cases—particularly in the instances of the Syenite walls—sulphuric acid vapors clearly do not affect anything within the stones. In some cases mortar contains the sulphates of lime and magnesia before it is used. Most of our lime is burned with coal, and a half dozen specimens of quick-lime from different lime-kilns yielded slight traces of the sulphates of lime and magnesia. If we accept the development of these traces of sulphates in the lime by coal burning, mortar is probably made and used now about as it has been for many years past, excepting also that mud is sometimes used in place of mortar. Much more sulphuric acid, however, is now generated within the city limits, particularly in winter, by the greatly increased use of coal.[1]

To avoid this white defacement developed from mortar, builders should use lime, free from magnesia, in erecting exposed brick-work. A demand for such lime will bring ample supplies from other localities, and at low prices.

Continuous exposure to sulphurous vapors may effect some change even in mortar made from lime containing no magnesia. But, as before stated, the great solubility of sulphate of magnesia, and its tendency to effloresce, make it the chief evil, and it is worth while to try the result of using purer lime.

When argillaceous limestone is burned, hydraulic cement is formed. The resulting mixture of lime and burned clay (usually with some

[1] Rain absorbs acid vapors contained in the air through which it falls, and driving rains from the northeast may thus acidify, as well as moisten, north and east walls.

sand), when wet, "sets" compactly, and the admixture of clay may, to some extent, protect the lime from such influences as might otherwise affect it injuriously. Portland (hydraulic) cement is made by burning an artificial mixture of limestone (chalk) and clay. Portland cement is believed to contain but a small proportion of magnesia, and this circumstance, in connection with that of the possible protective influence of the clay, justifies the supposition that walls built with this cement, may show less white defacement than those in which our ordinary mortar is used. Several brown-stone base-walls, laid in good cement, and particularly exposed to dampness, were examined, but showed no defacement. The painted walls of a room in the building of one of the Trust companies in this city, lately became much disfigured by the formation of efflorescent crusts of sulphate of magnesia and lime, from the decomposition of mortar within the walls. At the writer's suggestion, hydraulic cement was substituted for the mortar, and the walls re-painted. This has since remained unaffected. Cements vary in price and quality, from good to worthless.[1] Chimneys might be laid in cement, and if white markings between the bricks are desired, these can be painted or pointed with marble dust. This is nearly pure carbonate of lime, and is used in mortar for pointing. It appears to remain a long while unaffected, indicating that sulphuric acid vapors in the air exert little influence upon it. Plaster (sulphate of lime) is not generally used for pointing. Unless largely mixed with mortar it would crack off or be dissolved, and washed by rain over the bricks. Paint serves to some extent as a protection from dampness. The disfigurement may, however, be observed occasionally on painted brick walls after damp weather, the paint being discolored, and in some cases thrown off by the incrustation forming beneath it.

The unsightliness caused by the white incrustations is intensified by contrast with what may be termed the black streaks. On almost every brick house these hang repulsively at either end of each window-sill. They represent the repeated washings of dust and dirt

[1] White efflorescences, chiefly of the carbonates of soda and potassa, sometimes disfigure walls built with cement mortar. Rosendale cements frequently contain a large percentage of magnesia, together with soda and potassa. (*Vide* Gillmore on Limes, Hydraulic Cements and Mortars, N. Y., 1863.)

from window spaces and window frames. Scrubbing brushes, vigorously applied, might remove them. Any simple device would serve to divert the dirty drippings which soak the bricks beneath the windows, developing characteristic white patches here between the black streaks. As it is, the model Philadelphia brick house, with its white incrustations and black streaks, is a reproach and shame. Builders and brick manufacturers who prevent these evils in new houses, may reasonably expect to reap public gratitude, and, perhaps, something more satisfying. Entire blocks of houses have so changed countenance—have "so gone down"—within a single year, as to repel desirable tenants, when, indeed, they remained in all other respects unchanged. The subject under consideration has for a long time interested the writer from a utilitarian standpoint, rather than a scientific one.

EDISON'S CARBON TELEPHONE TRANSMITTER, AND THE SPEAKING PHONOGRAPH.

By S. M. Plush.

Both the telephone and speaking phonograph are instruments of American invention, and have undoubtedly excited more wonder and admiration throughout civilization than any previous inventions have done in ancient or modern times. Their novelty is still fresh, but when this fades away their practical uses will begin.

The telephone has already found its way into the counting-rooms and offices of our business and professional men, and reached almost the limit of its capacity. Quite recent improvements, however, have greatly increased its power, thus rendering it more efficient for all practical purposes, and widening the field of its usefulness.

These inventions, like all others, are not the result of one mind, nor the products of a day; on the contrary, they are the results of many men's diligent experiments, extending through a number of years. Based on the principle of the vibration of sound, Prof. Reiss, of Germany, constructed the first telephone in 1861. In this

instrument the electric current was broken by delicate springs, resting on a tightly-stretched membrane or diaphragm, which was thrown into vibrations corresponding exactly with the vibrations of the air, produced by the sound of the voice. The receiving instrument was constructed on the principle first demonstrated by Prof. Henry, that iron expands when under the magnetic influence of electricity, and returns to its normal condition when this influence is broken or removed. An electro-magnet, therefore, supported on a sounding box, and vibrated by these lengthenings and shortenings, made distinctly audible, at the receiving end, the vibrations of the membrane at the other.

This apparatus was capable of reproducing but one of the characteristics of sound, viz., pitch. Further experiment was necessary to reproduce its quality and dynamic force.

Elisha Gray, of Chicago, in 1874, gave to the world his harmonic telephone, based on the same general principles as that of Reiss. He succeeded in transmitting, at the same instant, several musical sounds of different pitch, and reproducing the same at almost any distance.

In 1876 came that of Prof. Bell, of Boston, consisting of a tightly stretched membrane, having a small permanent magnet fastened to its centre, in front of, and close to, the poles of an electro-magnet, charged by a galvanic current. Any disturbance or vibration of this membrane and permanent magnet, would necessarily induce a magneto-electric current in the coils of the electro-magnets and line, corresponding in all respects to the disturbing forces, in number, amplitude and duration of vibration, thus reproducing articulate speech. The receiving instrument consisted of a tubular electro-magnet of a single helix, surrounded by a soft iron cone, into the top of which was loosely fitted an iron plate, which was vibrated by the magnetizing action of the helix. Its capacity was extremely limited, the sounds were weak, and could be transmitted but a short distance. It, however, accomplished a great work in demonstrating the possibility of transmitting and reproducing articulate sounds.

Prof. Dolbear, of Boston, the same year, failing to see the importance of charging the line with a battery current, and believing it rather detrimental, substituted permanent magnets, with small electro-magnets around the poles, for the electro-magnets and galvanic

battery of Bell.[1] Another valuable improvement consisted in using the same instrument for sending and receiving, in lieu of instruments of different construction, as had been done previously.

As will be seen, when the vibrating motions of the air are concentrated on the diaphragm, as in speaking, a corresponding motion of it is produced; this, likewise, disturbs the magnetic condition of the magnetized bar, and induces electric currents in the surrounding helix, corresponding in all respects to the vibrations of the voice. Thus, by their electro-magnetic action upon an identical apparatus, placed in the same circuit, they will cause its diaphragm to vibrate in precisely the same manner as that of the transmitter. The principal peculiarity in this apparatus, and the one of vital importance to the transmission of articulate sounds, is that the electric current is never entirely broken, as is the case in the telephones previously described.

While all sounds may be faithfully transmitted and reproduced by this instrument, its capacity is not great, and when used on lines which are in close proximity to others heavily charged with electricity, the disturbing influence of induction is so great as to render these inaudible.

To overcome this difficulty, Thos. A. Edison, of Menlo Park, N. J., directed his attention to a series of experiments, and at length discovered that carbon, properly prepared, possessed the property of changing its conductivity by pressure, and that the ratios of these changes exactly correspond with the pressure brought to bear upon it. By varying degrees of pressure against a disc of carbon forming a part of an electric circuit, the resistance of the disc would vary exactly with the degree of pressure; a proportionate variation would, therefore, be occasioned in the strength of the current, which would thus possess all the characteristics of the vocal vibrations. By connecting this carbon disc in a local galvanic circuit, together with an induction coil, its power can be increased or diminished at pleasure. In its present state of development, conversation has been maintained between Philadelphia and Washington, a distance of 140 miles; while a magneto-telephone, placed in the same circuit, failed at 28 miles.

[1] The improvement in the telephone here credited to Prof. Dolbear, is also claimed by Prof. Bell, and is embodied in the instrument described on p. 219, vol civ., Oct., 1877, this JOURNAL. J. B. K.

Many modifications of the speaking telephone have been devised, but they all embrace one or other of the principles hereinbefore described. That of G. M. Phelps, New York, called the duplex telephone, characterized by its peculiar excellence of articulation, is perhaps the most prominent.

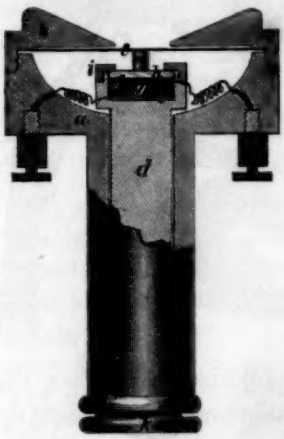
Fig. 1 represents the carbon transmitter of Edison, above referred to.

g, the carbon disc.

e and *f*, two thin platinum plates, connected in the local circuit.

Resting on the platinum, *f*, is a small disc of glass, *h*, of the same diameter as the carbon. On this glass plate rests a short brass tube, *m*, fastened to the round metal plate, *c*. This plate does not vibrate as the diaphragm in the ordinary telephone, being quite rigid; it simply arrests the atmospheric concussions, and conveys them, by direct contact, to the carbon disc.

Fig. 1.



b, the mouthpiece.

a, hard rubber case.

d, a core extending through the handle from the platinum, *e*, to the nut, *k*, to which it is connected by a movable screw, so arranged as to be capable of any desired longitudinal adjustment.

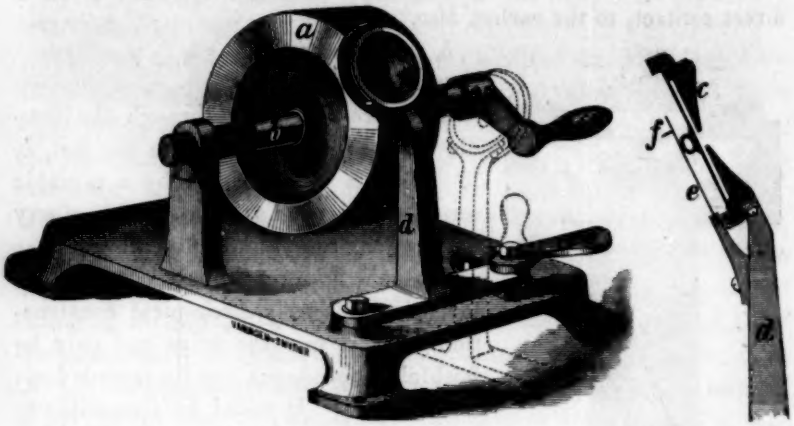
Edison's speaking phonograph is an invention of purely mechanical construction. By it can the voice not only be faithfully reproduced, but its records kept for centuries. It would be impossible to even conjecture the uses to which this wonderful instrument may be put. Time and the necessities of our people only, can determine this. It, like the telephone, depends for its action upon the vibrations of a metallic diaphragm, capable of receiving from, and giving to, the air, sound vibrations. It consists of a cylinder, Fig. 2, *a*, mounted on a horizontal axis, *b*, extending each way, beyond its ends, a distance of about its own length. In the circumference of the cylinder, a spiral groove is cut its entire length. The shaft is also cut by a screw-thread (16 to the inch) corresponding to the spiral groove of the cylinder, and works in screw bearings. When, therefore, the

cylinder is made to revolve by means of the crank attached to the end of the shaft, it moves horizontally to the right or left.

The diaphragm is supported in an iron box, mounted on a standard, *d*, Figs. 2 and 3, in front of the cylinder, *a*, and so arranged that it can be swung to or from it at pleasure, or the stylus adjusted to any required delicacy. To the centre of the diaphragm is cemented a small piece of rubber tubing; against this rests a delicate spring, *e*, Fig. 3, permanently fixed at its lower end, having a sharp-pointed stylus in the other.

To operate the phonograph, the cylinder is smoothly covered with tin-foil. The crank then turned to the left, until the cylinder has

Fig. 2. Fig. 3.



reached its limits. The stylus is now so adjusted, that when the cylinder is turned, it makes a slight depression in the foil directly over the groove.

By turning the crank, the whole length of the cylinder will pass in front of the stylus from right to left; the stylus having traversed the whole length of the groove. Any sound or speech made in the mouthpiece, *c*, while the cylinder is in motion, will be correctly recorded on the foil. The diaphragm will vibrate with the voice, and the soft and yielding foil will be marked along the line of the groove by a series of indentations, corresponding in every particular with the vibrations of the voice. Thus the yielding but inelastic foil re-

ceives and retains the mechanical impressions of the vibrations of the human voice with all their minuteness and subtle characteristics. These permanent impressions of the voice having been made, it is only necessary to remove the diaphragm, and turn the crank to the left until the cylinder is again in its normal position, when, by replacing the diaphragm, and placing in the mouthpiece a large funnel of paper to reinforce the sound, then turning the crank at the same speed as at first, we obtain from these impressions the aerial vibrations which made them.

Fig. 4.

Fig. 4 represents a small section—magnified two diameters—of tin from the phonograph, called the matrix, containing a record of speech, by Henry Bentley, President of Phila. Local Tel. Co., March 23d, 1878, showing number and length of vibrations. The amplitude is not here shown, but would form a line of short and long curves, the curves varying with the force of the sound.

As an exact representation of sound is nothing more than a reproduction of similar acoustic vibrations in a given time, it is imperatively necessary that the cylinder revolve at a uniform speed and perfectly steady motion to obtain a faithful reproduction of the human voice.

French Narrow-Gauge Railways.—The railway from Commentry to Montluçon, with a gauge of one metre, carries 400,000 tons per annum. The Orleans company has built the road of Mondalazac, with a gauge of 1·10 m., for the transport of ores. The "Compagnie du Nord" has taken under its patronage a number of small companies; it guarantees bonds, makes advances, and aids by its advice. Among the companies thus aided and protected are the road from Hermes to Beaumont, 31 kilometres; from Marle to Rosoy, 28 kilom.; from Auvin to Fiéthun, 95 kilom.; all of 1 m. gauge.—*Ann. des Ponts et Chaussées.* C.

Water Supply of London.—In 1874 water was supplied to 3,655,000 lodgers, in 511,000 houses; the daily quantity of water was 526,612 cubic metres, or a little less than 144·96 litres per head. Eight companies, with a total capital of 281,218,500 francs, perform this service, paying average dividends of 6·3 per cent. In 1877 the number of inhabitants was 3,796,000, lodging in 533,000 houses; the daily consumption rose to 600,225 cubic metres, giving, for the summer months, a daily supply of 158·55 litres per head. A moderately heavy fire may require the concentration, on a given point, of about one-tenth of the whole supply, or a quantity of water sufficient, during the same time, for a city of 100,000 inhabitants. It has been proposed to have two distinct systems, of which one should be reserved for the extinction of fires. It would require only 135,000 cubic metres, a quantity which could probably be furnished by springs from the chalk-beds. It would be necessary to establish reservoirs at elevated points, and a new pipe system. The water department receives a subsidy of about 2,000,000 francs, or in the neighborhood of 574 francs per 1000 inhabitants. Paris, with 1,986,000 inhabitants, expends 2,500,000 francs, or about 1250 francs per 1000. New York, with a population of 1,098,000, expends 6,270,000 francs, or 5850 francs per 1000. Chicago, with a population of 550,000, expends 2,790,000 francs, or 5075 per 1000. —*Ann. des Ponts et Chaussées.* C.

Corrosion of Engines and Boilers by Fatty Acids.—In some steam-generators, especially in re-heaters, tubercular deposits are formed, clinging closely to the iron, which is commonly corroded at the point of contact as if by an acid. This brownish material has sometimes a greasy feel, and smells like burnt grease. Experiments, by Stingle, Wartha and Bolley, have shown that the deposit is due to the oxidation of the fatty lubricants. It may be prevented by neutralizing the fatty acid by some alkali. Milk of lime is the most economical, and quite effectual.—*Bull. de la Soc. Ind. de Mulhouse.* C.

Diffusion of Gases.—Sigmund v. Wroblewski has deduced the following general law: When a gas is absorbed, it diffuses itself through the absorbing body in the same way as heat spreads in a solid rod, whether the absorbing material is liquid, viscous, or solid. —*Ann. der Phys. u. Chem.* C.

Photo-Electricity.—The marked influence of sunlight on the electric conductivity of selenium, led Börnstein to experiment with other metals. He concluded that all bodies were affected by photo-electricity, but G. Hausemann, at the suggestion of Dr. Werner Siemens, entered upon investigations which appear to contradict Börnstein's views. Dr. L. A. Forssmann, of Stockholm, finds that even the selenium experiments do not seem to depend upon the influence of either the luminous, the thermal or the chemical rays; but upon waves of some other octave, or even, perhaps, upon longitudinal vibrations.—*Ann. der Phys. u. Chem.* C.

Metallurgy of Nickel.—M. Badoureau gives a complete essay on the treatment of nickel ores, in the *Annales des Mines*, vol. xii, pp. 237–340. C.

Study of the Ultra-Violet Solar Spectrum.—Angström limited his admirable memoir upon the Normal Spectrum of the Sun, to the visible portion. Cornu has extended it to the extreme limit which can be observed photographically, by the aid of a spectroscope, with objectives of quartz and a prism of Iceland spar. The limit thus attained is marked by the ray U, with a wave-length of 294·80. He has added two plates to Angström's atlas, of the same form and on the same scale.—*Comptes Rendus.* C.

Telephone Experiments.—From some observations by A. Demoget, of Nantes, we select the following: It is desirable that the plates should vibrate in unison with the sounds which are transmitted. The voices of women and children are best heard with plates of 3 to 5 centimetres' diameter; those of men, with plates of 6 to 8 centimetres. If the gamut is sung in a telephone with a large disc, the first low notes will be easily heard, while the highest notes will be less distinct; if the disc is small, the highest notes will be most clearly heard. At one end of a line two telephones may be placed in double circuit, and if two persons sing simultaneously in the two instruments, the two voices will be heard in a single telephone at the other end of the line. M. Demoget proposes to experiment with two or three telephones of different pitch, in a sort of acoustic horn, in the hope of getting more intense and more distinct sounds.—*Les Mondes.* C.

New Cooling Agent.—Ch. Tellier has used trimethylamine for the production of cold, under conditions which lead him to regard it as the best known frigorific. Vaporizing at + 8° C., under ordinary pressures, it requires a pressure of only from one to two additional atmospheres to reliquefy it. This property allows us to utilize waste heat, especially the waste steam of manufactories, so that the cost of the refrigeration is limited to the bare expense of superintendence. A degree of cold equivalent to that produced by the consumption of 10,000 kilogrammes of ice, can thus be obtained for a few francs.—*Les Mondes.* C.

Hydrogenium.—Fifty years ago, Dumas announced his belief that hydrogen was a vaporized metal. At first he found few to agree with him, but subsequent experiments, by different chemists, led many to admit the probable existence of a metal called *hydrogenium*. The recent experiments of Cailletet and Pictet exhibited minute crystals, confirming this view. Dumas thinks this confirmation may be of great practical industrial importance. "The positive knowledge of the metallic nature of hydrogen would have an important influence in metallurgy; industry would reap the benefit of it;" and on these accounts the late experiments should excite a lively interest among the friends of labor, as well as among devotees of science.—*Soc. d'Enc. pour l'Ind. Nat.* C.

Telephone Relays.—DuMoncel, in speaking of recent experiments by Pollard and Garnier, suggests the use of a telephone which should be both receiver and transmitter. Its local battery might act as a relay by the intervention of the induction coil, thus increasing the sounds and transmitting them to great distances.—*Comptes Rendus.* C.

Parisian Scientific Conferences.—The French Scientific Association has organized a series of conferences, to be held at the Sorbonne. Their object is to make known and explain new inventions and discoveries. Their programme embraces repetitions of Cailletet's experiments on liquefaction and solidification of gases; explanations by H. Ste.-Claire Deville; a discourse by Dumas, on the history of the association and its services to science; and other interesting features. Dumas proposes that the association should open a subscription for a monument to its founder, Le Verrier.—*Les Mondes.* C.

New System of Pile-Driving.—Messrs. Stoecklin and Vetillart, in their works for enlarging the harbor of Calais, found great difficulty in sinking the piles and plankings through the fine, moist beach-sand. The use of water to facilitate the penetration of broken iron piles, suggested its use on the outside and in advance of the wooden logs that they were using. By the help of two hand-pumps the sand was so loosened and held in suspension, the labor was greatly abridged. On the old plan, an average of 185 blows was required to drive a pile, 900 blows for a panel, requiring, on an average, 8 hours 36 minutes. With the help of water injection, the number of blows per panel varied from 0 to 50, the mean time being only 1 hour 9 minutes; many of the panels required only from 14 to 16 minutes, and the longest time was only 1 hour 45 minutes. The extraction of displaced or broken piles or planking, which has hitherto been attended with great difficulty, is accomplished with the greatest ease by the new system.—*Ann. des Ponts et Chaussées.* C.

Connection of Electro-Magnetic Rotation with Uni-Polar Induction.—Edlund has studied the currents which are generated by the rotation of a cylindrical magnet, surrounded by a metallic mantle which can be turned on the same axis. Letting $s_1 =$ strength of current generated by rotation of the mantle, $k =$ a constant depending on the condition of the mantle and the position of the points where the conductor touches the mantle, $M =$ magnetic movement of the magnet, $w =$ angle described in unit of time, and $l =$ resistance of conducting wire, he finds $s_1 = \frac{k M w}{l}$. He explains the several results obtained by various rotations of the magnet and mantle, in accordance with his general hypotheses, by accumulations of æther at various points.—*Ann. der Phys. u. Chem.* C.

Loss of Power in Steam Engines.—J. Illeck publishes in the *Journal of the Austrian Association of Engineers and Architects*, a discussion of the loss of efficiency in consequence of some of the principal sources of waste and condensation in steam engines. C.

Aluminium Telegraph Wires.—Aluminium has been recommended as a coating of telegraph wires, because its electric conductivity is about twice as great as that of iron.—*Berg- u. Hütten-Zeitung.* C.

The Douro Bridge.—The Northern Portuguese Railway has lately completed a fine work of engineering skill, in a bridge over the Douro, at a point where its breadth is 140 metres, and its depth 18 metres. The bed is sand and mud, with a thickness varying from 15 to 56 metres. The river is subject to great and rapid freshets, which sometimes raise the surface 12 or 13 metres in 24 hours. The railway reached the bank of the stream at a height of 60 metres above the low water level, and at this height the distance between the banks was 350 metres. The construction of a viaduct, under the circumstances, presented serious difficulties. Plans were presented by four firms, and the one offered by G. Eiffel & Cie., of Paris, was adopted. It was impossible to think of building a pier in the river; it was therefore spanned by a single iron arch, of 160 metres spring, a little larger than the central span of the St. Louis bridge. The arch abuts against piers of masonry on each bank; there are two other piers on one side, and one on the other, at distances varying from 29 to 37 metres. The central arch is crescent-shaped, formed by two parabolas, intersecting at the abutments and having a height of 10 metres at the summit. It is composed of two principals, hinged at the abutments, so as to allow for changes of temperature; at starting they are 15 metres apart, but the distance is reduced to 4 metres at the summit. This arrangement was made in order to secure effective resistance to the violent winds which are frequent in the valley, and all the trellis-work, both of the roadway and of the piers, was planned for the same purpose. The mounting of the arch presented great difficulties, on account of the impossibility of erecting scaffolding, but by the help of steel cables, crossing the river at the level of the platform, the two halves, simultaneously constructed, met at the key with absolute precision.—*Ann. des Ponts et Chaussées.* C.

Estimation of Sound-Velocity by the Method of Coincidences.—Akos Szathmari has modified König's method, by substituting a pendulum current breaker for the tuning-fork. He finds a velocity, in dry air at 0° C., of 331·57 metres, which is nearly an arithmetical mean between the results obtained by Regnault (330·7) and by Moll and Van Beck (332·26). He claims as advantages for his method, the ease with which it can be employed, and the fact that it requires only a small space, in which the temperature and moisture of the air are uniform.—*Ann. der Phys. u. Chem.* C.

Disaggregation of Tin.—Organ-pipes, after long use, become brittle and fall to pieces. Oudemans stated (*Chem. Jahresber.*, 1872, p. 256) that plates of pure tin, which contain, at most, 0·3 per cent. of lead and iron, break into small fragments, like molybdenum-sulphide, in the railway transport from Rotterdam to Moscow, in severe cold weather. A similar phenomenon has been lately observed at the Royal Pyrotechnic Laboratory in Spandau. A large quantity of tin plates (295 kilogs.) became exfoliated and crumbled into small particles. Still later, larger quantities of Billeton block tin (1950 kilogs.) were similarly affected. The warehouses were thoroughly dry; the tin contained only traces of foreign metals, no sulphur or phosphorus, and no tin-oxide. According to Dr. Petri's account, the tin could be pulverized more easily than ordinary tin filings, and gave out hydrogen more quickly with acid. While it was in the warehouse there was no severe cold, yet the disaggregation went on.—*Ann. der Phys. u. Chem.* C.

A New Sense.—M. E. Cyon has sent a note to the French Academy, in which he claims that the eighth pair of cerebral nerves contains two nerves of entirely distinct senses—the auditory nerve, and the nerve of space (*Raumnerv*). He regards the latter as the source of all our ideas of extension, and of the three dimensions of space. C.

Electro-Motive Force of Water in Capillary Tubes.—Dr. H. Haga publishes the following results of his investigations upon the electro-motive force which is generated by the flow of water in capillary tubes. The potential difference is proportional to the pressure; it is independent of the length of the tubes; it is modified by the nature of the inner wall of the tube; it increased with the resistance of the water; it probably increases with the temperature. J. W. Clark finds that: 1. The narrower the tube, the greater is the force. 2. In very fine tubes, the force is independent of the length; in larger tubes it diminishes with the length. 3. Covering the inner wall with different substances, the force varies, as Quincke ascertained. 4. The force diminishes with time, whether the water is flowing or at rest; the original force may be restored by cleansing the tubes with sulphuric acid and distilled water. 5. The seat of the force is in the bounding area of the water and the tube.—*Ann. der Phys. u. Chem.* C.

On Some Physical Points connected with the Telephone.[1]—This instrument may be employed both as a source of a new kind of current and as the detector of currents which are incapable of influencing the galvanometer. It shows that the form and duration of Faraday's magneto-electric currents are dependent on the rate and duration of motion of the lines of force producing them, and that the currents produced by the alteration of a magnetic field vary in strength with the rate of alteration of that field; and further, that the infinitely small and possibly only molecular movement of the iron plate is sufficient to occasion the requisite motion of the lines of force. He pointed out that the telephone explodes the notion that iron takes time to be magnetized and de-magnetized. Mr. R. S. Brough has calculated that the strongest current employed in a telephone is $\frac{1}{10000000000}$ of the CGS unit. Mr. Preece explained that the dimensions of the coil and plate depend on the strength of the magnet, but the former should always consist of fine wire and be made as flat and thin as possible. The adjustment of the position of the magnet (as near as possible to the plate without touching) is easily effected by sounding a vowel sound *ah* or *o* clearly and loudly; a jar is heard when they are too near together. After briefly enumerating the attempts which have been made to improve the instrument, he mentioned the various purposes to which it can be applied. In addition to being useful to the lecture room in conjunction with several well-known forms of apparatus, it forms an excellent detector in a Wheatstone bridge for testing short lengths of wire, and condensers can be adjusted by its means with great accuracy. M. Niaudet has shown, by employing a doubly wound coil, that it can be used to detect currents from doubtful sources of electricity, and it is excellent as a means of testing leaky insulators. Among the facts already proved by the telephone, may be mentioned the existence of currents due to induction in wires contiguous to wires carrying currents, even when these are near each other for only a short distance. Mr. Preece finds that if the telephone wire be enclosed in a conducting sheath which is in connection with the earth, all effects of electric induction are avoided; and, further, if the sheath be of iron, magnetic induc-

[1] From a Paper read by Mr. W. H. Preece before the Physical Society, January 19th, 1878.

tion also is avoided, and the telephone acts perfectly. A great number of experiments on the use of the instrument on telegraphic lines were then described, from which it appears that conversation can be carried on through 100 miles of submarine cable, or 200 miles of a single wire, without difficulty, with the instrument as now constructed. The leakage occurring on pole-lines is fatal to its use in wet weather for distances beyond five miles. An interesting series of telephones was exhibited, and, by means of one of very large dimensions, Mr. Preece showed that the current produced by pressing the centre of the plate sensibly affects a Thomson galvanometer, and that the motion of the needle ceases in a remarkably instantaneous manner, as soon as the pressure is removed, a necessary condition, in order that the receiving-plate should accurately reproduce the motions of the sending-plate.—*Chemical News.*

Liquefaction of Gases.—M. Tissandier points out that M. Cailletet's experiments fully confirm the theory, first put forward by Andrews, that there exists for the permanent gases a critical point of pressure and temperature, above which they cannot be reduced to a liquid condition. It is found for each gas that a certain pressure has to be combined with a certain lowering of temperature. Either cold or pressure, separately employed, gives no result, even at great degrees of intensity. It is perhaps owing to their not having been subjected to a sufficiently energetic joint action of these agents that the permanent gases were able to retain their intractable independence hitherto, in spite of the attacks made on their freedom. M. Berthelot himself has experimented with pressures up to 800 atmospheres and cold down to — 100° C. M. Cailletet found that binoxide of nitrogen retained its gaseous form at the pressure of 270 atmospheres and the temperature of + 8°. But combining the points critical for marsh-gas—180 atmospheres and + 7°—it was liquefied. The same experimenter finds that atmospheric air, dried and freed from carbonic acid, is converted, when at a pressure of 310 atmospheres, into a true hoar frost, while at a pressure of 200 atmospheres the appearances on the inside of the tube were similar to those occasioned by the trickling down of a subtle fluid like ether. At 255 atmospheres the threads of fluid were much more visible.—*Iron.*

Solar Photography.—M. Janssen is acquiring new and valuable knowledge relative to the structure of the sun's disc, by means of large images and brief photographic exposures. He is thus enabled to neutralize the effects of irradiation. By means of a special and very perfect mechanism, he has reduced the time of exposure to $\frac{1}{3000}$ of a second, obtaining sharply-defined images corresponding to discs of more than a metre in diameter.—*Comptes Rendus.* C.

Fall of the Western Approach to South Street Bridge.—At a quarter after seven o'clock on the morning of February 10th, the western approach to the South Street Bridge, 420 ft. in length by 55 ft. in width, and consisting of nine masonry arches, fell into the marsh a complete wreck. About three months before a slight settlement of the second pier from the western end of the structure was observed, but no cracks being found, no immediate serious danger was apprehended.

The necessity for taking immediate steps for the preservation and repairs soon became apparent, and on the morning in question a gang of men were at work shoring up, when suddenly the pier sank rapidly at its northern end, and almost immediately fell, carrying with it the two arches resting upon it. This removing the resistance to the thrust of the remaining arches, they fell also.

The structure consisted of nine segmental arches of 43½ ft. clear span and 14 ft. rise, resting on piers 5½ ft. thick, 13½ ft. high, by 55 ft. long. The piers, in turn, rested on foundations consisting of 84 piles, averaging 10 ins. diameter, placed 3 ft. apart. The piles were cut off 2 ft. below low water mark, and the earth excavated 2½ ft. below this, and the cavity filled with concrete. On top of, and ragbolted to, the piles, was a double course of 8 in. by 8 in. grillage, the interstices of which were also filled with concrete; over this was a platform 10 ft. by 60 ft., consisting of two courses of 3 in. hemlock plank, placed diagonally and spiked to the grillage.

Mr. D. McN. Stauffer, engineer in charge of the construction, states that "each and every pile under the structure had four final blows applied from the 2000 pounds hammer, and the full height of the drop (36 ft.), and if it did not descend more than 1 in. in these four blows, it was considered home." He also states that the piles under the pier which failed, were driven to a depth of 19 ft., where they encountered a hard stratum believed to be gravel.

Many causes have been assigned for the failure of the structure, after standing for nearly eight years, but it must be confessed that none of them are entirely satisfactory, nor is the true cause likely to be ascertained until a thorough examination is made, probably involving an excavation or boring to the bed-rock.

The cause assigned by Mr. Stauffer, is that "the tremor produced in the piles, by travel on the bridge, would loosen them sufficiently to allow the percolation of water down their sides, and finally throw the entire weight on the toes of the piles, and if the gravel on which they rested was merely a thin bed or pocket, the water probably softened it, allowing the piles at the north end of the pier to drop through to the mud."

In a paper read before the Engineers' Club, Prof. Haupt, from data obtained from the drawings in the office of the chief engineer and surveyor, estimated the pressure placed upon each of the piles to have been a little more than 36 tons, and says: "As the piles * * * were driven through, or into, soft mud inundated at every tide, * * * it is evident that there could have been very little lateral support from that source; and hence the pressure placed upon them, and so nearly equal to that which the same number and size of piles would support when driven in a compact soil, was in excess of their bearing power, and the cause of the fall of the structure."

Since the above was written, Chief Engineer Smedley has furnished the following information on the subject:

"Levels taken six days prior to Feb. 10th, did not show any appreciable difference from those taken three days before; but from the 5th to the 8th the settlement per day increased from ·03 ft. to ·07 ft. On the afternoon before the fall it sank from ·02 ft. to ·03 ft. per hour. The last 24 hours amounted to ·6 of a foot, when it settled, nearly vertical, 17 ft. at the north end, and 7·5 ft. at the south end. The whole surface of the meadow, within 20 ft. of the debris, was raised about 4 ft.

"The soundings have since been taken to rock, which was reached at 28·4 ft. below low tide, at the south end of pier, and 31·1 ft. at the north end. At 30 ft. north of the bridge, the rock was found at 25·4 ft.

"The whole of the sounding was through stiff muck, except a stratum, of about 2 ft. thickness, mixed with sand, which was somewhat harder, and found in each case at 17·1 ft."

It would, therefore, seem probable that the piles had rested on this stratum of gravel, which is supported on soft material, as shown by the soundings, and that the frictional support being destroyed by the action of the tides and tremor of the structure, the piles pierced or broke up the gravel stratum. The mass once in motion, its momentum would be sufficient to crush the piles, even if the slope of the rock had been sufficiently flat to hold them at their toes. *

Launch of the City of Rio de Janeiro.—The largest iron steamship ever built at Chester, with two exceptions, the Peking and Tokio, was successfully launched from Roach & Sons' yard, on March 6th, at half-past two o'clock P. M. The first frame was raised on the fifth day of November, 1877, and therefore but four months and one day were consumed in her construction. The new vessel was christened the City of Rio de Janeiro, and is the first of four steamships being constructed by the Messrs. Roach for passenger and freight traffic between New York and Brazil. Everything about her is of American manufacture.

The Rio de Janeiro is 370 feet long over all, 39 feet beam. Depth of hold from base line to top of spar deck is 31 feet 6 inches, and she will be of three thousand and five hundred tons, custom house register. She has three decks beside the hurricane deck. The spar, main and hurricane decks are entirely of iron. All the deck frames and the deck houses are also of iron.

The machinery proper consists of two compound surface condensing engines of 2500 horse power, and with separate engines for working the air and circulating pumps. The propeller is of brass, of the Hirsch patent, having four blades, and it is 16 feet in diameter.

She will be barquentine rigged; the lower masts, being iron, will be used as ventilators. The dining saloon is one hundred and thirty feet long by forty feet broad in the widest part. From the dining saloon is a spacious staircase leading up to a large and elegant social hall fitted with rare hard woods. In this hall there will be fourteen elegant staterooms, fitted with sofas, washstands, and with berths, arranged for one or two persons; the upper berths rolling back in the same manner as those used in the Pullman palace cars.

The maximum passenger capacity will be for one hundred first class passengers, and four hundred persons in the steerage.

She will be provided with eight metallic life-boats, the carrying capacity of which will be from 35 to 60 persons each, and with four life-rafts, which, altogether, will carry 700 persons.

The Rio de Janeiro was built under the special supervision of the French Bureau Veritas, and the American Ship-Masters' Association, of New York, and will have the highest rate. *

Book Notices.

ENGINEERING SPECIFICATIONS AND CONTRACTS. By Louis M. Haupt, C.E. 8vo., pp. 300. Philadelphia, J. M. Stoddart & Co. 1878.

Defective specifications often result in loss of time and money, in the erection of works, to an extent equally disastrous, from a financial point of view at least, as defective designs, and it is, therefore, very important that engineers should be able to prepare those papers in the best possible manner.

It is true that in most of the offices of our older engineers, are to be found files of such documents, which have done excellent duty, and serve as models to those having access to them. A large proportion of our young engineers, however, have not such resources to fall back upon, and even if they had, have not the experience or knowledge necessary to select the best; moreover, the student of engineering should be made familiar with the preparation of such papers, not only for the value of such knowledge in his future practice, but to give him a better conception of such problems as may be given him, illustrative of the studies he is pursuing.

A work covering this ground has been needed, and to supply this want the author was prompted to prepare this one, and which he has done with excellent judgment.

The preparation of "contracts" more properly belongs to the legal profession, but it is important that the engineer should be consulted in connection therewith, that there may be no ambiguity as to the intention of the parties thereto upon any of the engineering features; that portion of the book devoted to this subject is, therefore, quite appropriate.

The work is divided into six chapters, and at the end of each is a series of questions relating to its contents, adding to its value as a text book, while copious marginal notes facilitate references.

The two subjects mentioned comprise Chapters III and VI, covering 150 and 40 pages respectively, and contain well selected examples of documents prepared, for the most part, for works now completed.

Chapter I contains a concise statement of what is required in good drawings, intended to form the basis of contracts.

Chapter II, on estimates and measurements, besides other important matter, gives the rules of the Carpenters' Co. of Philadelphia, for measuring carpenters' and joiners' work.

The facts and forms contained in Chapter IV, relating to advertisements, and Chapter V, on bids or proposals, and the glossary of technical terms in the appendix, will be found very useful. *

A Handbook of Volumetric Analysis. Designed for the use of students in colleges and technical schools. By Edward Hart, S. B., Fellow of Chemistry, in the Johns Hospital University, Baltimore. John Wiley & Sons, N. Y. Price, $2.50.

Chemical analysis has become a branch of modern education so important, that good text books for students, embracing the essential features of the science, with the improved processes of recent investigators, are not more numerous than the demand.

From the greater rapidity with which results can be obtained by *volumetric* analysis, it will always commend itself to those engaged in technical work.

In the present volume the author has given so much of the work of Dr. Mohr as has stood the test of experience, and brings the subject up to the present time, in a condensed form. To the foreign literature on the subject, is added some practical information derived from American chemists, whose opportunities render their observations valuable. As a handbook for students, and to those engaged in technical analysis, the book will be of value. B.

PROCEEDINGS OF SOCIETIES.

The American Institute of Mining Engineers held its February meeting for this year, in Philadelphia. The first session was held at the rooms of the American Philosophical Society, February 26th, at 8 o'clock P. M.

The President, Prof. T. Sterry Hunt, presented the opening address, upon "The Earth's Atmospheric Envelope during the Carboniferous Age;" and the following papers were read:

"The Manufacture of Artificial Fuel at Port Richmond," by Mr. E. F. Loiseau.

"The Economy Effected by the Use of Red Charcoal," by Mr. Bernard Fernon.

A note on "Manganese Pig-Iron," by Dr. R. W. Raymond.

The second session was held at the Franklin Institute, on Wednesday, at 10 A. M. Dr. T. M. Drown read a paper on "Pulverized Zinc, and its Uses in Analytical Chemistry;" and Prof. J. S. Smock, on "The Fire Clays and Associated Plastic Clays, Kaolins, Feldspars and Fire Sands of New Jersey."

A note, by Mr. P. Barnes, on "The so-called Blue Process of Copying Tracings," was also read.

The third session was held at the Academy of Natural Sciences, on the afternoon of Wednesday, when the following papers were read:

"The Nickel Ores of Oxford, Quebec, Canada," by Mr. E. C. Eustis.

Note on "The Drainage of a Flooded Ore Pit, at Pine Grove, Pennsylvania," by J. Birkinbine.

"The Strength of Wrought Iron, as affected by its Composition and by its Reduction in Rolling," by A. L. Halley.

"An Improved Tripod for Surveying Instruments," by J. H. Harden.

"A Suspended Signal for Surveying," by Prof. H. S. Munro.

The closing session was held at Memorial Hall, Centennial Grounds, on Thursday morning.

Papers were read on "Some New Points in the Geology of Lancaster Co., Pennsylvania," by Prof. Persifor Frazer, Jr.

"Red Charcoal in the Blast Furnace," by Wm. Kent.

"Some Minerals from Sterling Hill," by Professor S. G. Koenig.

Note on "The Cost of Construction of the Converting Works of the Edgar Thomson Steel Co., of Pittsburg, Pennsylvania," by P. Barnes.

"Index of the Geological Reports of the Various States and Territories," by Prof. F. Paine, Jr.

"The Late Workings of the Mariposea Estate," by Charles M. Roelker.

"A Filter for Boiler Water," by P. Barnes.

"Memoranda showing the Percentage of the different Expense Accounts in Mining Hematite Ore at Manhattan Mine, Sharon Station, N. Y.," by J. F. Lewis.

Engineers' Club of Philadelphia.—At the meeting of the club held Feb. 16th, Mr. Charles A. Ashburner read a paper[1] on the "Oil Sands of Pennsylvania," in which he gave an outline of their distribution over the State, together with their geological position, character, etc.

The percentage of risk of obtaining "dry holes," which the producers experienced in the different districts, was referred to, and the statement made that the risk is greater in the southern and western districts and least in the northern—it being only about three per cent. in the latter. Specimens of the sands and crude oils exhibited, added to the interest in the paper.

Mr. Geo. H. Christian followed with a paper on the "Lowe Gas Process," giving a description of the apparatus, and the chemical changes which the material undergoes in the course of manufacture, together with an estimate of the first cost and maintenance of the plant. The paper was illustrated by a large sectional drawing and a general view of the new gas-works at Lancaster, Pennsylvania.

At the meeting held March 2d, twenty-two members were present.

Mr. Rudolph Herring read a paper on the "Sewerage of Philadelphia," in which he gave an outline of our system of house and street drainage, and he pointed out "some of the defects, together with their remedies, which, if not securing a complete immunity from disease, would remove a powerful agency for evil," and concludes that "the whole subject, especially the house drainage, needs sincere and early attention and study. But more than that, it needs *action*."

A paper by Prof. L. M. Haupt, on the "South Street Bridge," was next read. From data obtained from the office of the City Engineer, he estimates the pressure on the piles forming the foundations for the piers of the western approach to be about 36 tons to each pile having an average diameter of 10 inches. These piles "were driven through and into a soft mud inundated at every tide; the pressure placed upon them was in excess of their bearing power in such soil, and the cause of the fall of the structure."

Mr. Geo. Burnham gave a general description of the masonry work of the bridge, and presented a plan which he believed could have saved a portion of it. The subject was discussed by a large number of members.

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[1] See page 225, this volume.

Franklin Institute.

HALL OF THE INSTITUTE, March 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

The attendance of members and visitors was very large, filling the lecture room to its utmost capacity; the number estimated at 375.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute; the following donations to the Library were reported:

Maps of the Battle-field of Gettysburg, in three sheets. From Chief of Engineers.

Specifications and Drawings of Patents for August and September, 1877. From U. S. Patent Office.

Annual Report of the Board of Regents of the Smithsonian Institution, for 1876. From the Institution.

Papers relating to Foreign relations of the United States, for 1877. From Secretary of State.

Progress and Resources of New South Wales. By Chas. Robinson. Sydney, 1877.

Journal and Proceedings of the Royal Society of New South Wales, 1876. Vol. 10. Sydney, 1877.

Railways of New South Wales. Report by John Rae. From 1870—1875, incl. Sydney, 1876.

Annual Report of the Department of Mines, New South Wales, for 1876. Sydney, 1877.

Climate of New South Wales. By H. C. Russell. Sydney, 1877.

Kamilaroi, and other Australian languages. By Rev. W. Ridley. 1875. From Royal Society, New South Wales.

Fifth Annual Message of the Mayor of Philadelphia. 1877. From the Mayor.

Annual report of the Light House Board, for 1877. From the Board.

Geological Survey of New Jersey. Report on the Clay Deposits. Trenton, 1878. From the State Geologist.